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December 1973

Journal OF THE Fisheries Research Board OF Canada

Announcement

This issue is comprised of 2 Parts. Part 1 is the regular December issue, and Part 2 contains papers prepared for the Technical Conference on Fishery Management and Development of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

An author–subject index and list of all publications issued during 1973 will be published in early 1974, and distributed free to all Journal recipients, including subscribers. Additional copies will be available through the Office of the Editor.

J. C. STEVENSON
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Light intensity and photosynthetic rates in phytoplankton

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HARRIS, G. P., AND J. N. A. LOTT. 1973. Light intensity and photosynthetic rates in phytoplankton. J. Fish. Res. Board Can. 30: 1771–1778.

The physiological behavior of various phytoplankton species has been examined under increasing and decreasing light regimes. A marked asymmetry has been found, with photosynthesis rates under rising light intensities exceeding those under dimming lights. Photoinhibition has been observed at moderate light intensities (0.4–1.0 ly/min). Variations in the asymmetry and in photoinhibition appear to be correlated with the light regimes experienced by the population. Under constant illumination by full sunlight a steady decrease in the photosynthesis rate was observed. As a result of photosynthesis measurements in fluctuating light regimes there is now evidence for photorespiration as the controlling mechanism. Data are presented which show that prolonged exposure to high light has an adverse effect on photosynthesis and indicate that ^{14}C moored bottle experiments may show reduced surface rates because of this.

HARRIS, G. P., AND J. N. A. LOTT. 1973. Light intensity and photosynthetic rates in phytoplankton. J. Fish. Res. Board Can. 30: 1771–1778.

Les auteurs étudient le comportement physiologique de diverses espèces phytoplanctoniques exposées à des régimes ascendants et descendants de luminosité. Ils observent une asymétrie prononcée des taux de photosynthèse à des intensités lumineuses dépassant celles d'un éclairage réduit. Il y a photoinhibition à des intensités lumineuses modérées (0.4–1.0 ly/min). Les variations de l'asymétrie et de la photoinhibition semblent liées aux régimes lumineux auxquels la population est habituée. A une illumination constante en plein soleil, il y a diminution uniforme du taux de photosynthèse. A la suite de mesures de photosynthèse à des régimes lumineux variables, on a des indications que la photorespiration est le mécanisme de contrôle. Les auteurs démontrent, avec données à l'appui, qu'une exposition prolongée à une forte intensité lumineuse nuit à la photosynthèse et que, pour cette raison, les expériences au ^{14}C avec bouteilles ancrées peuvent donner des taux de surface trop bas.

Received March 7, 1973

OF the available methods for measuring primary production by phytoplankton the most frequently used have been photosynthetic oxygen evolution and carbon^{-14} uptake. The light and dark bottle carbon^{-14} technique of Steeman-Nielsen (1952a) has been the main method used. In this technique photosynthesis is measured by lowering pairs of bottles containing $H^{14}CO_3^-$ to fixed depths for time periods of 1–5 hr, or by incubating the bottles under known conditions of light and temperature. These techniques, however, do not take into account the dynamic nature of the aquatic system.

The ^{14}C moored bottle profiles commonly show reduced uptake rates at the surface — a phenomenon which has been called photoinhibition (Findenegg 1965, 1971; Curl and Small 1965; Vollenweider and Nauwerck 1961). This photoinhibition has been a familiar feature of algal physiology for a number of years. Steeman-Nielsen (1952b, 1962) has suggested that inactivation of part of the photochemical mechanism is a means of protecting the cell from high light damage. Kessler (1960) reviewing the topic offered no conclusive evidence for the mechanism of photoinhibition except to say that at very high light intensities (two to three times normal sunlight) chlorophyll bleaching occurs. Steeman-Nielsen (1952b, 1962) suggests that enzyme inactivation accounts for the rapid drop in photosynthesis rates observed at lower light intensities before any chlorophyll bleaching is demonstrated.

Photorespiration (Goldsworthy 1970) is a mechanism which would cause an apparent decrease in the net photosyntheses rate ("photoinhibition"). The oxidation of photosynthetically produced glycolate consumes O_2 and produces CO_2 in the light leading to an apparent decrease in the observed photosynthesis rate. Photorespiration has been observed in blue-green algae (Lex et al. 1971; Döhler and Koch 1972) and higher plants (Goldsworthy 1970). It has also been observed that the

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photosynthesis rate of an alga (*Acetabularia*) decreases with time in continuous light (Van den Driessche and Bonotto 1972).

In this paper we examine the evidence for the occurrence of photorespiration in planktonic algae. We have made photosynthetic rate measurements with oxygen electrodes under simulated natural conditions and the results are compared with (a) the photosynthetic effects of exposure to a constant light intensity (as shown by cells moored in a bottle at a fixed depth) and (b) the effects of exposure of free floating cells to increasing and decreasing light intensities.

Methods

Phytoplankton material for physiological study was taken either from culture or from net tows in Lake Ontario in 1972. Laboratory cultures (originally obtained from the Indiana University culture collection) were grown in Erlenmeyer flasks that were shaken and had air bubbled into them. Cultures were grown on a 5% soil: water extract at a temperature of 18 C and at a light intensity of .022 ly/min on a 12-hr L-D cycle. The cultures were not maintained bacteria-free but the cells were washed before use if contamination was serious.

Field collections and experiments were carried out on Lake Ontario. In the field, zooplankton (particularly rotifers) were found to be a problem due to oxygen consumption by respiration and as a result a procedure was developed to disrupt zooplankton while minimizing damage to the phytoplankton. A net-tow with a 180 mesh/inch phytoplankton net was taken and the resulting 250-ml sample homogenized with a Virtis 45 homogenizer at 45,000 rpm for 1 min. The sample was then centrifuged for 30 sec at 3000 × g to concentrate the sample before photosynthesis measurements were made. This process took 4–5 min and care was taken not to expose the cells to direct sunlight during this time. Microscopic examination of the samples after this procedure revealed no gross structural damage to the majority of the phytoplankton while most rotifers and cladocerans were disrupted. Comparisons with unhomogenized plankton suspensions indicated a small decrease in photosynthesis rate after homogenizing (0, 6, and 8% decrease in three replicate trails). Although this technique causes disruption of some cells, it does allow purely algal oxygen exchange to be measured. The decrease in photosynthesis rate is small compared to the effect of removing zooplankton respiration when zooplankton are abundant. Bacterial contamination was not considered to be important for the <2-hr short runs.

Photosynthesis measurements were carried out using Clark oxygen electrodes and Gilson KMC oxygraphs. Short-term (<2-hr) runs used the standard 1.5-ml cuvette. Temperature control (±0.1 C) was achieved by circulated water from a refrigerated water bath. Light was supplied by a tungsten photoflood source which was concentrated by a spherical water boiling flask and calibrated with a Moll–Gorczynski solarimeter. Oxygen supersaturation in the medium was prevented by bubbling in N_2 at intervals; large pH fluctuations (>1.0 units) were prevented by titrating with CO_2. These relatively crude controls were found to give repeatable photosynthesis rates during short-term determinations.

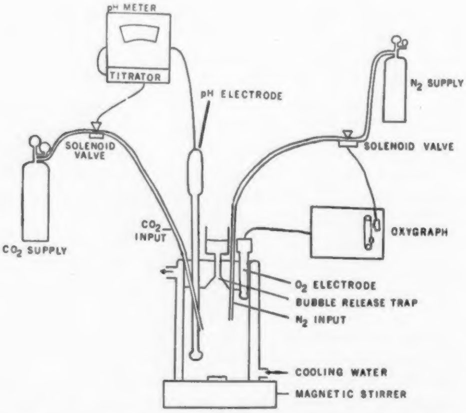

FIG. 1. Titrated oxygraph apparatus showing the flow systems for N_2 and CO_2.

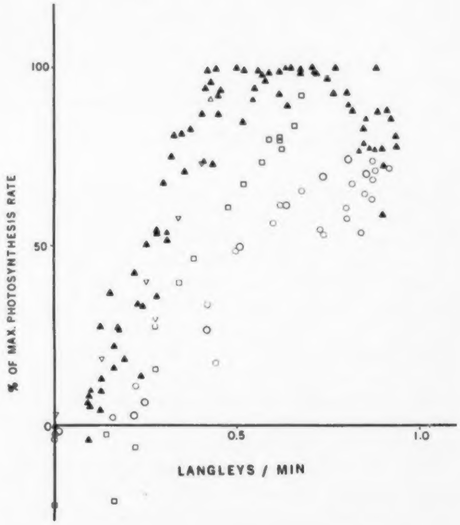

FIG. 2. The relative rate of photosynthesis plotted against light intensity for *Cosmarium botrytis* in March 1972 (2-hr cycle). ▲ all increasing light gradient responses, △ the return response from a maximum of 0.34 ly/min, □ the return response from 0.65 ly/min, ○ the return response from 0.98 ly/min.

For long-term experiments (> 2 hr) a 150-ml cuvette was used and the CO_2 and N_2 bubbled in automatically (Fig. 1) to maintain the *p*H within 0.1 units and the O_2 level within ± 10% of saturation.

Measurements were carried out at 18 C (the growth temperature) in laboratory culture experiments and at 17–20 C (surface lake temperatures) in the field in July. Some photosynthesis rates were normalized by expressing the rate at each light intensity as a percentage of the maximum rate.

Two light regimes were used both of which called for variable intensities rising to a predetermined maximum and falling again to dark. The short-term runs (<2 hr) were carried out using a hand-controlled calibrated variable-voltage transformer to dim a 150 w tungsten bulb. Stepped light intensities were generally used. Long-term experiments (>2–16 hr light) were programed by a specially built camless programer. This programer allowed time on, rate of increase of light intensity, maximum light intensity, rate of decrease, and time off to be preselected. Programs were selected to simulate natural summer conditions in the field. Photosynthesis measurements were made by measuring the rate of O_2 evolution over a period of 50–60 sec while the light intensity was constant. Graphs of photosynthesis rate vs. light intensity were then plotted relating the rate to increasing and decreasing regimes.

Analysis of chlorophylls was carried out by the method of Strickland and Parsons (1968). A Zeiss PMQII spectrophotometer with 5-cm semi-micro cuvettes was used for the determinations.

Cell counts were performed either by direct counting on a Zeiss UPL inverted microscope (all field counts), counting at least 500 cells, or by electronic counting using a model F Coulter counter with a 280-μ pore (single species cultures).

Results and Discussion

On first examination of the results of both short- (Fig. 2–5) and long-term (Fig. 7) light cycles a marked asymmetry is obvious. Rising light regimes give enhanced photosynthesis rates compared to falling regimes. This would indicate that photoinhibition, which occurs after saturating light intensities, is never completely reversed in the light.

The photoinhibition effect of high light intensities has been reported before (Steeman-Nielsen 1962; Setlik 1967) and is now recognized to be a wide-

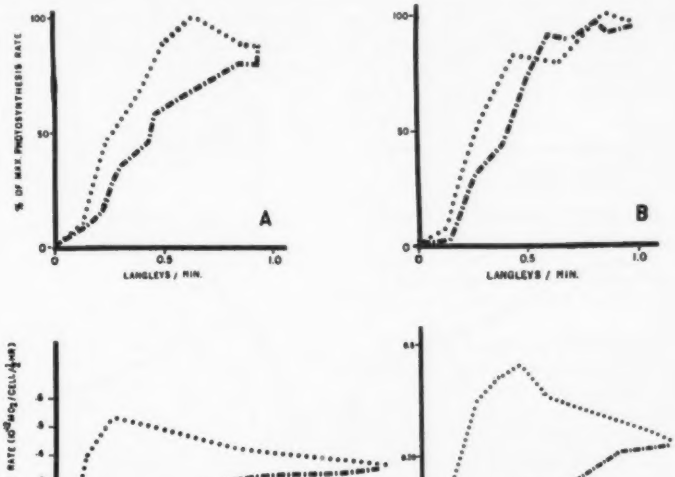

FIG. 3. The response of phytoplankton to short-term rising and falling light regimes (···· rising, —·—·— falling). A, *Scenedesmus quadricauda* maximum intensity 0.95 ly/min; B, *Chlorella ellipsoidea* maximum intensity 0.95 ly/min; C, *Sorastrum* sp. maximum intensity 0.6 ly/min; D, *Melosira* sp. and *Asterionella* sp. from Lake Ontario maximum intensity 1.15 ly/min. Ordinates for B and D, the same as A and C, respectively.

spread phenomenon among planktonic algae. We have demonstrated the effect in *Cosmarium botrytis* Menegh, (Fig. 2), *Scenedesmu squadricauda* (Turp.) Bréb. (Fig. 3A), *Chlorella ellipsoidea* Gerneck, though not markedly (Fig. 3B), *Sorastrum* sp. (Fig. 3C) and mixed field populations from Lake Ontario dominated by *Melosira* sp. and *Asterionella* sp. (Fig. 3D and as yet unpublished data). We have also observed the effect with blue-green algae and species of *Euglena*.

It was noted that the physiology of *Cosmarium botrytis* Menegh. in culture changed with time as shown by the results from June 1971 (Fig. 4A), November 1971 (Fig. 4B), and March 1972 (Fig. 2). It has since been observed that plankton in the field can become "sun" or "shade" adapted (Fig. 5) in less than 2 hr, thus indicating a rapid response of the cells to their environment.

The magnitude of the asymmetry in photosynthesis rate was dependant on the maximum light intensity reached in relation to the saturation light intensity (Fig. 2, 4A and B). Maximum intensities at or below saturation produced little asymmetry whereas intensities above saturation produced increasing effects

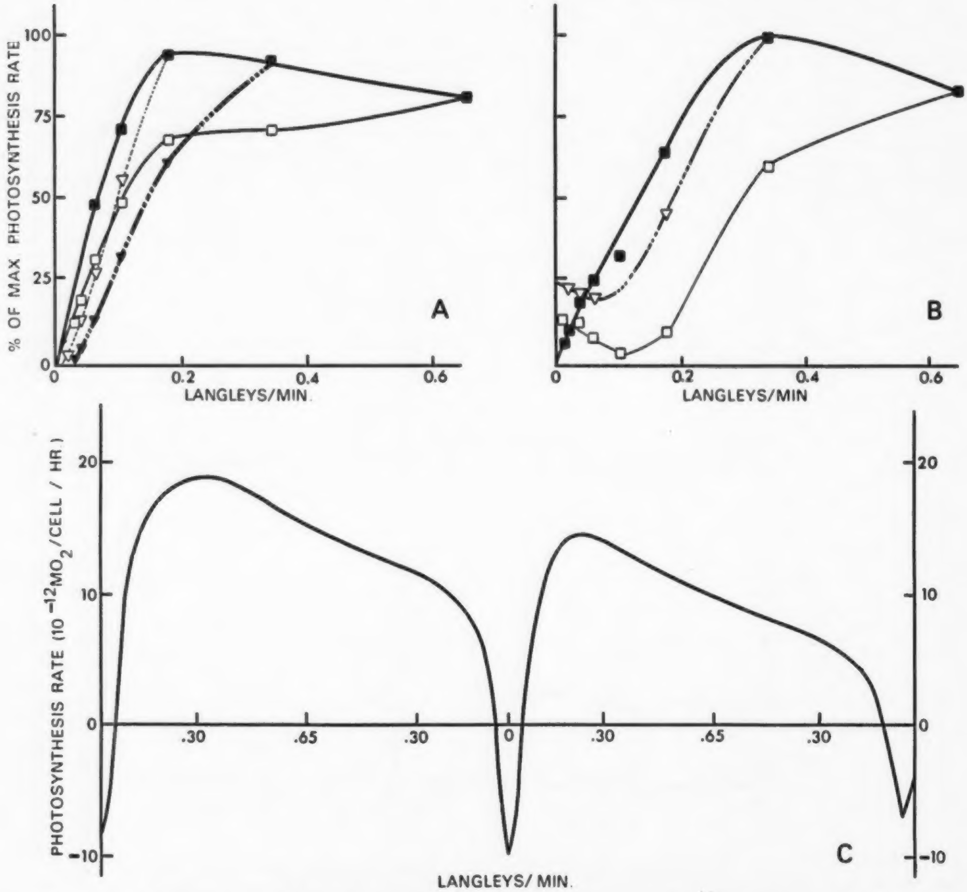

FIG. 4. Polynomial fitted curves for five replicate experiments with *Cosmarium botrytis*. ■ All rising light intensity data, ----- the return response from 0.18 ly/min, ——-----— the return response from 0.34 ly/min, ☐ the return response from 0.65 ly/min. A, June 1971; B, November 1971; C, A double light regime showing complete reversibility after dark treatment for 5 min. Ordinate for B the same as A.

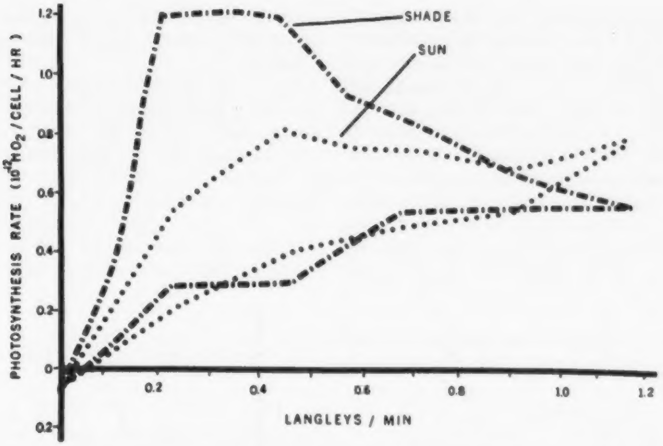

FIG. 5. The photosynthetic responses of mixed *Melosira* sp. and *Asterionella* sp. populations from Lake Ontario, April 1972. Populations were collected after surface sun or shade conditions in the previous 2 hr.

(Fig. 2). Experiments were carried out to determine the nature of this photoinhibition effect. Chlorophyll a + b (10^{-12} g/cell) contents for *Cosmarium botrytis* were determined under a 1.5-hr rising and falling light regime with a maximum intensity of 1.0 ly/min. Samples were taken in the dark, at .34 ly/min with the light intensity rising and at the same point with the light intensity decreasing. Determination of chlorophyll content of *Cosmarium* during increasing and decreasing light regimes indicated no significant change in chlorophyll content on a per cell basis as seen below:

	Dark	.34 ly/min rising	.34 ly/min falling	Dark
Number of replicates	6	7	7	6
mean chlorophyll (a + b) content per cell 10^{-12}g/cell	.531	.575	.570	.557
standard deviation	.046	.053	.037	.048

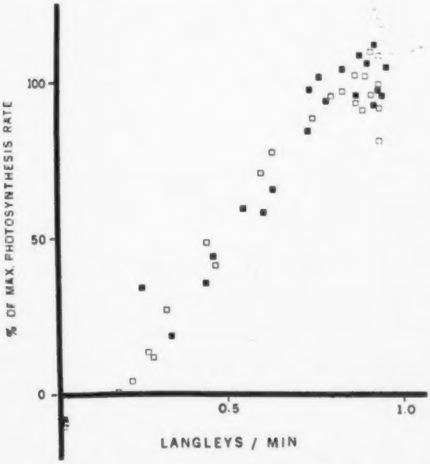

FIG. 6. The photosynthetic response of a mixed population of *Melosira* sp. and *Asterionella* from Lake Ontario to a short-term rising and falling light regime at 13% oxygen saturation. The superimposed results of two replicate experiments are shown.

Chlorophyll bleaching has been reported at very high light intensities (Kessler 1960) but as the photoinhibition effect is produced very rapidly once the saturation point is reached such rapid loss of chlorophyll at light intensities less than full sunlight would be surprising.

It was observed at an early stage that the photoinhibition effect was sensitive to changes in the dissolved oxygen concentration. Increases in the dissolved oxygen concentration in the cuvette caused a decrease in the apparent photosynthesis rate. Lowering the oxygen concentration to 13% saturation by bubbling N_2 through the cuvette caused the photoinhibition and asymmetric photosynthesis rates to be completely erased (Fig. 6). This dependance on O_2 concentration is the standard test for photorespiration (Goldsworthy 1970). This oxygen sensitivity together with the rapid dark reversibility of photoinhibition (Fig. 4C) leads us to believed at this stage that photorespiration is a likely cause of the observed changes in photosynthesis rates. If photorespiration is indeed taking place then the apparent photosyntheiss rate is being affected by the oxidation of photosynthetically produced glycolate with a consequent consumption of oxygen.

It is not possible for this asymmetry and photoinhibition effect to be due to nutrient limitation for various reasons. First, the effect was dark reversible (Fig. 4C); second, we were measuring photosynthetic oxygen evolution not cell division and growth; and third, calculations for cultures and lake water media have shown that adequate supplies of nitrogen and phosphorus existed for the duration of these experiments.

The results of the long-term experiments (5–8 hr) with both Lake Ontario populations (Fig. 7A and B) and with *Cosmarium* in culture (Fig. 7E) gave similar results. Using a light regime which simulated a cloudless day, photoinhibition near maximum intensity was observed. On a long-term basis (2–3 hr at up to 8.0 ly/min), however, this photoinhibition may be reversible to give a recovery of the photosynthetic rate during the "afternoon" de-

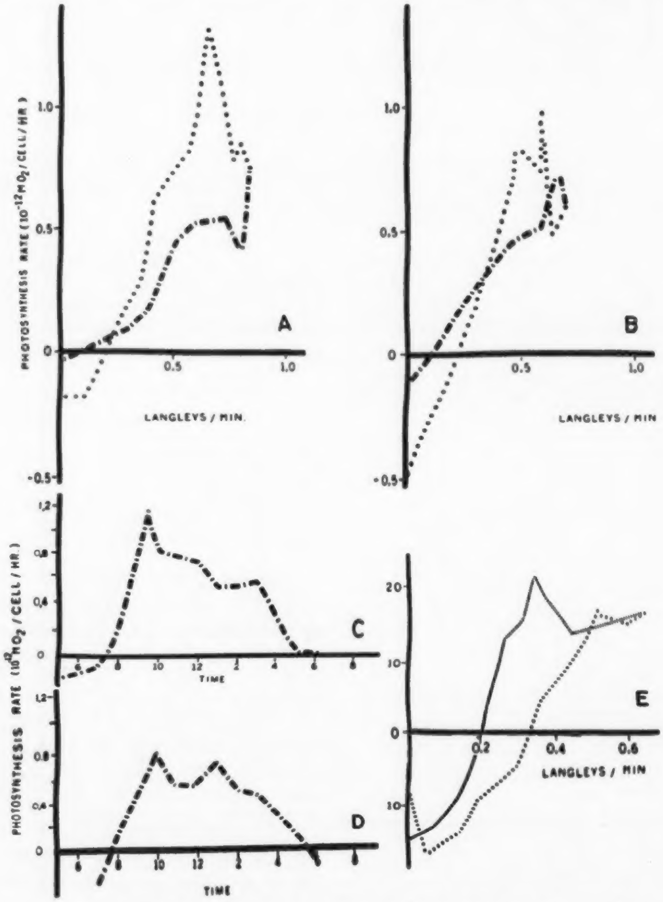

FIG. 7. Photosynthetic responses of phytoplankton to 8-hr light regimes. *Melosira* sp. and *Asterionella* sp. from Lake Ontario. A, maximum intensity 0.86 ly/min; B, maximum intensity 0.72 ly/min; C, and D, the interpolated day rate curves corresponding to A and B; E, *Cosmarium botrytis* maximum intensity 0.65 ly/min. Ordinate for B and E the same as A.

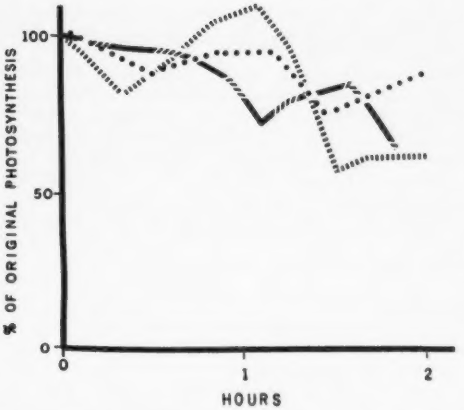

FIG. 8. The effect of continuous exposure to constant light intensities of 1.02 ly/min (····), 0.68 ly/min (—···—···), and 0.45 ly/min (////////) for 2 hr. Mixed diatom populations from Lake Ontario in April 1972 were used and were pretreated by increasing the light intensity to the predetermined level by the short-term route.

creasing light period. Asymmetric photosynthesis curves can be observed when light regimes up to 1.0 ly/min are used, with little or no "afternoon" recovery. With lower maxima (approx. 0.72 ly/min) a clear afternoon recovery was noticeable (Fig. 7D). At lower intensities a symmetrical curve with a peak photosynthesis rate occurring at the maximum light intensity is produced (Vollenweider 1969; Vollenweider and Nauwerck 1961). These types of responses reproduce a field depth profile of maximum photosynthetic rates in a lake before noon at the surface, maximum rates before and after noon at 1-3 m depth and at noon at greater depths. These profiles are now being observed by ^{14}C techniques in the Great Lakes and elsewhere (Vollenweider and Nauwerck 1961, and P. Stadelmann personal communication). They represent the static state in the lake in unmixed water columns or when ^{14}C bottles are anchored in situ. Except on windless days this situation is not representative. Days when the wind speed exceeds 4 m sec^{-1} occur 70% of the time in January–March and 45% of the time in June–August (analysis of Toronto meterological data 1969). Vertical mixing by turbulence and Langmuir cells, by moving the plankton populations vertically in a light gradient, will ensure that no cells are exposed to high light continuously for more than a few minutes. If cells are exposed experimentally to continuous light intensities of up to 1 ly/min (Fig. 8) the apparent rate of photosynthesis declines with time (Van den Driessche and Bonotto 1972) indicating a possible build up of photosynthates and a consequent rise in the photorespiration rate. Observations in the field indicate reduced photosynthesis by populations at the surface in bottles on clear, sunny days. Vollenweider and Nauwerck (1961) found that the production total of three or four short ^{14}C bottle incubations exceeded the 24-hr total of one long incubation, which would indicate that cells anchored in bottles at various depths for long periods underestimate the true production rates particularily at the surface (Vollenweider and Nauwerck 1961). It would thus seem possible that the fluctuating light conditions such as would be found in mixed water columns best suit the algal populations for the maintenance of continuous high photosynthesis rates.

Acknowledgments

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Diel and Annual Cycles of Net Plankton Photosynthesis in Lake Ontario

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HARRIS, G. P. 1973. Diel and annual cycles of net plankton photosynthesis in Lake Ontario. J. Fish. Res. Board Can. 30: 1779–1787.

Photosynthesis measurements on net plankton have been carried out for the period April, 1972 to January, 1973 in Lake Ontario. The rising and falling light regimes used on the net phytoplankton (>64μ) give marked photosynthetic hysteresis effects in winter and in spring for diatom-dominated populations. Diel fluctuations in photosynthesis and "sun" or "shade" adaptations showed a close interaction between the phytoplankton and the surface light intensity. Systematic seasonal changes have been recorded in the magnitude of the photosynthetic hysteresis effect, saturation light intensities, compensation points, maximum photosynthesis, and respiration rates. An inverse correlation has been found between net plankton mean maximum photosynthesis rates and the rate of change of water temperature. Also phytoplankton respiration rate is largely a function of temperature.

The data have been unified to give a picture of daily photosynthesis patterns at different depths in a static water column. The data compare well with ^{14}C moored bottle experiments. Predictive equations have been calculated for maximum photosynthesis rates at different times of the year.

HARRIS, G. P. 1973. Diel and annual cycles of net plankton photosynthesis in Lake Ontario. *J. Fish. Res. Board Can.* 30: 1779–1787.

Des mesures de photosynthèse ont été effectuées sur le plancton tamisé du lac Ontario d'avril 1972 à janvier 1973. Les régimes en hausse et en baisse d'intensités lumineuses utilisées sur le phytoplancton tamisé (>64 μ) produisent un effet hystérésie photosynthétique marqué en hiver et au printemps sur des populations où dominent les diatomées. Les variations nycthémérales de la photosynthèse et l'adaptation au "soleil" et à "l'ombre" démontrent une étroite interaction entre le phytoplancton et l'intensité lumineuse à la surface. On a enrégistré des changements saisonniers systématiques dans l'ordre de grandeur de l'effet hystérésie photosynthétique, intensités lumineuses de saturation, points de compensation, photosynthèse maximale et taux de respiration. Il y a corrélation inverse entre le taux maximal moyen de photosynthèse du plancton tamisé et le taux de variation de la température de l'eau. De plus, le taux de respiration du phytoplancton est en grande partie fonction de la température.

Nous avons agencé nos données de façon à présenter un tableau journalier de la photosynthèse à différentes profondeurs dans une colonne d'eau statique. Les données se comparent favorablement avec celles obtenues au ^{14}C avec bouteilles ancrées. Nous avons calculé des équations permettant de prédire les taux maximums de photosynthèse à différentes périodes de l'année.

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MEASUREMENTS of photosynthetic activity by phytoplankton in the field have been almost exclusively carried out by $H^{14}CO_3^-$ in the light and dark bottles (Steeman-Nielsen 1952). There are no published measurements for photosynthesis by phytoplankton in Lake Ontario except that of Glooschenko et al. (1973). Work in Lake Erie (Verduin 1962; Saunders 1964; Parkos et al. 1969; Glooschenko et al. 1974) and in other aquatic systems (Curl and Small 1965; Findenegg 1971; Vollenweider and Nauwerck 1961) indicates that rates of production in the Great Lakes are of the same order of magnitude as production rates elsewhere.

If a basic understanding of primary production by phytoplankton is to be achieved, then a detailed knowledge of daily and seasonal photosynthetic responses is required. This series of detailed photosynthesis measurements was specifically designed to provide the data base for a lake production

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simulation model relating photosynthesis to light intensities and water mixing.

Methods

Collection of phytoplankton was carried out from the M.V. *Martin Karlsen* at two stations in Lake Ontario, IFYGL master stations 19 (43° 35′ 24″ N, 78° 00′ 42″ W in midlake) and 11 (43° 46′ 30″ N, 78° 51′ 18″ W off Oshawa, Ont.) from April 1972 to January 1973. Collections were also made in July 1972 only from a barge moored 5.6 km NW of Niagara-on-the-Lake, Ont. Cells were collected in the field by towing a 64-μ mesh phytoplankton net vertically from 10 m. The resulting net plankton were further concentrated by sieving at a mesh size of 64 μ to a volume of approximately 250 ml. This suspension was then blended at 45,000 rpm for 1 min to disrupt the zooplankton and then centrifuged at 3000 × *g* for 30 sec to concentrate the cells. This process was developed (Harris and Lott 1973a) so as to effectively remove respiring zooplankton whilst leaving the phytoplankton relatively undamaged.

After centrifugation, the pellets were placed in the 1.5-ml cuvette of a Gilson KMC oxygraph and measurements of oxygen evolution by photosynthesis were made with a Clark electrode. The light intensity was varied by hand-controlled variable transformer running a tungsten source. The light beam was concentrated by a water-filled spherical lens and was calibrated by means of a Kipp solarimeter.

A specialized light regime was used to simulate the effects of vertical mixing. The light intensity was raised from dark (5 min) to 1.15 ly/min (approx surface intensity) in eight steps taking 50 sec per step and a photosynthesis rate measurement was made at each step. Light intensity was then decreased in the same way giving a rising and falling regime intended to simulate the light regime of a population moving in a Langmuir cell. These cells are known to be operating under windy conditions in Lake Ontario (Harris and Lott 1973b).

Photosynthesis rates were expressed as 10^{-12} M O_2/cell per hour by counting cell numbers on an inverted microscope. Sufficient fields were counted to give a cell count of at least 1000.

Measurements of ^{14}C uptake were carried out at Niagara by incubating water and phytoplankton samples in 300-ml BOD bottles with 6.6 μc $H^{14}CO_3^-$ for 2 hr (Strickland and Parsons 1968). Light bottles were suspended at the surface and at 1, 3, 5, and 7 m with dark bottle controls at 1 and 5 m. The water samples were collected with a Van Dorn bottle at the depth of incubation. Daily series of 2-hr incubations were commenced at as near to the following times as possible: 0530, 0830, 1130, 1330, 1530 EST. After incubation the cells were filtered out on 0.4 μ Sartorius membrane filters, dried, and counted on an end window Geiger counter (Strickland and Parsons 1968) at a later time. Relative rates are given only in counts per minute as the daily pattern is clearly visible and in the absence of cell counts no direct comparison with the oxygen data is possible.

Simple computer simulation routines were constructed to allow the data to be converted to daily rates. Day rate estimates are based on half hourly solar radiation data measured over the lake in August by Davies et al. (1970). Data from a cloudless day was used in all cases, giving a symmetrical radiation distribution about solar noon.

Results and Discussion

From the results obtained it is evident that there are both daily and seasonal fluctuations in the photosynthetic response of cells to the rising and falling light regime.

DIEL PERIODICITY

The daily fluctuations in maximum photosynthetic rate at saturation intensity and the degree of photoinhibition indicated a close relationship between the algae and their environment. In April the diatom assemblage of *Melosira*, *Asterionella*, *Tabellaria*, and *Fragilaria* showed daily adaptations particularly well. Figures 1, 2, and 3 show how the cells altered their photoinhibition sensitivity, the magnitude of the hysteresis effect and their overall rates during the day. The hysteresis effect of decreased photosynthesis rates during falling light regimes (Setlik 1967) is now thought to be caused by photorespiration (Harris and Lott 1973a). Saturation and photoinhibition are thought to be caused by the oxidation of photosynthetically produced glycolate. Reduction of the light intensity slows the rate of photosynthesis while photorespiration is in operation thus adversely affecting the overall net oxygen balance.

The spring diatom populations in April showed a remarkable response to the ambient light intensity at the surface, the change from "shade" to "sun" forms of response (Fig. 1) took place certainly

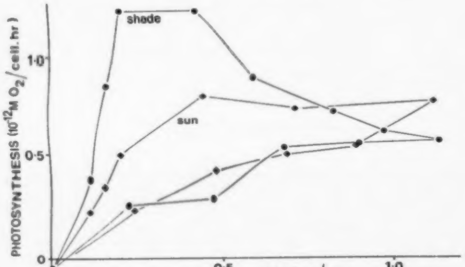

FIG. 1. Response of the spring diatom assemblage to the short-term rising and falling light regime. The response follows the upper part of the curve when light intensity is increasing and the lower part when light intensity is decreasing. The two types were taken from the lake under sunny and cloudy conditions.

within 2 hr. This is a more rapid response than previously has been recorded (Jorgensen 1969). Chlorophylls during this time showed no change (W. A. Glooschenko personal communication), so we are evidently observing physiological adaptation. The plot of daily maximum photosynthetic rates at different times of the day indicated a depression of (Fig. 3) photosynthesis around noon and a recovery in the afternoon. The depression was associated with the shift in response shown in Fig. 1. Similar results have been obtained using $H^{14}CO_3^-$ (Table 1). This noon depression is observed clearly only on clear sunny days. As Fig. 2 indicates "shade" types may exist all day on cloudy days giving no noon depression. There appeared to be a smooth response of physiological type in relation to ambient surface intensity (Fig. 2). There was constancy in the response at 0700–0800 hr before the day pattern of "sun" or "shade" was adopted. The small increase in light intensity from dark to 0800 hr caused the cells to shift their physiology so that "sun" or "shade" adaptation took place after that time depending on the surface solar radiation intensity.

Daily fluctuations in photosynthetic rate showed no clear pattern in May and June while the diatom populations were on the decline. Data from this period leave a little to be desired as the rotifer populations were very high in certain areas and caused difficulties in measuring the photosynthesis rates.

In July at Niagara, the maximum photosynthesis rates showed a clear diel periodicity which corresponds to the April data (Fig. 3). Inshore in July the phytoplankton was composed of mostly *Pediastrum*, *Ceratium*, and *Staurastrum* but despite the change in species the diel response was similar to that in April.

In September, the diel changes were not well marked although inshore at Oshawa the populations showed great sensitivity to sun conditions at the surface (Fig. 4). From a low rate of photosynthesis under conditions of low solar radiation at the surface, the appearance of full sun at the surface induced an increase in respiration sufficient to prevent compensation by the population. This change occurred within a time span of 1 hr in a population dominated by *Staurastrum*, *Ceratium*, and many small colonial green algae. The September pattern was therefore one of low photosynthesis rates in the early morning or under cloud, whereas under sunny conditions compensation was never reached. It is worth noting that at that time the net-passing nannoplankton (<64 μ) were actively photosynthetic in the sunshine.

TABLE 1. Relative photosynthesis rates from $H^{14}CO_3$ incubations at Niagara in July. Times indicate start times for 2-hr incubations at the indicated depths. 6.66 μc/300-ml bottle $H^{14}CO_3$ was used. Units are in counts per minute with controls subtracted.

Time EDT	Depth (*m*)				
	Surface	1	3	5	7
0600–0700	7092	3518	2505	972	442
0900–1000	4665	7082	6115	2232	671
1200–1300	3110	5039	5934	3129	923
1400–1500	3817	6330	4442	1757	717
1600–1700	2522	4342	3498	2614	1238

In fall and winter the diel fluctuations in photosynthesis were masked by cloudy weather and fewer experiments in rough weather. There is evidence from the December and January data that similar adaptations are taking place to those observed in April.

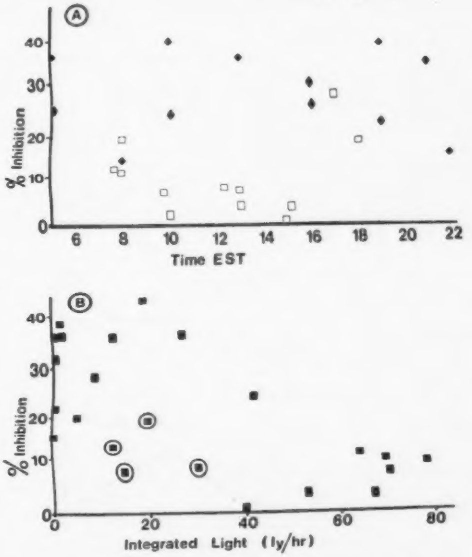

FIG. 2. April photosynthetic responses. (*Top*) Percentage decrease in photosynthesis rate from the onset of saturation to maximum light intensity for various times of day. ♦ cloudy conditions ☐ cloudless conditions. (*Bottom*) Percentage decrease in photosynthesis from saturation to that at maximum light intensity plotted against the integrated light intensity in the previous hour (langleys/cm^2 per hr). The circled points are all for 0700–0800 hr data which showed little photoinhibition.

There is a clear diel periodicity in the rate of respiration (Fig. 3). The increase in the basal dark respiration rate during the day is presumably due to the increased availability of photosynthetic products. The asymmetry of the photosynthetic response is correlated in time with the rise in the rate of respiration. The failure of the population to recover completely its morning maximal rate of photosynthesis may therefore be due to an increased respiration rate lowering the rate of net oxygen evolution.

Calculations of daily curves for photosynthesis at a number of depths using data presented above and information from Harris and Lott (1973a) reproduced many of the features observed by 2-hr ^{14}C bottle incubations (Table 1). Checking the oxygen data against ^{14}C data lends credibility to the experimental technique.

Extrapolation of the short-term rising and falling light regime curves (e.g. Fig. 1) to a long-term cloudless day situation gives daily estimates shown in Fig. 5. This incorporates data from Harris and Lott (1973a), which showed that at lower than maximum light intensities the magnitude of the hysteresis effect is reduced. This therefore indicates irreversible photoinhibition at the surface in a static water column and symmetrical daily curves at lower depths (see Vollenweider and Nauwerck 1961). The physiology changes throughout the day, however, and the adaptation and noon depression discussed above leads to extrapolation from data presented here to give daily photosynthesis re-

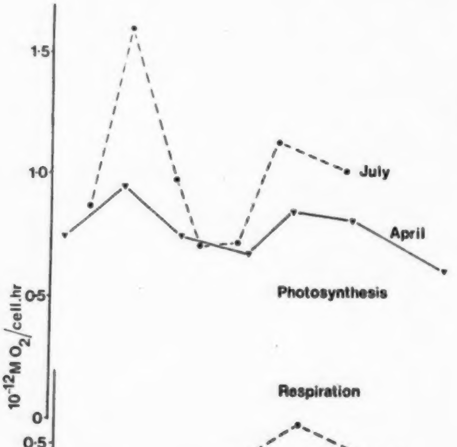

FIG. 3. (*Upper*) Daily trends of maximum photosynthesis rate recorded in April and July. Maximum photosynthesis rate is defined as the maximum rate at saturation light intensity. (*Lower*) Daily trend of dark respiration rate for A summer and B spring, fall, and winter populations.

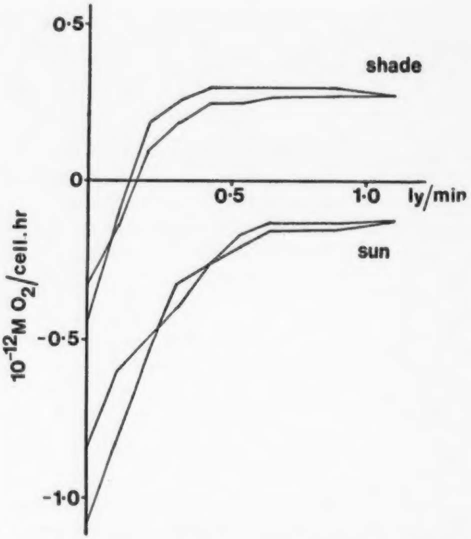

FIG. 4. The sun/shade changes observed at the Oshawa station in September. Note the large increase in respiration rate under sun conditions.

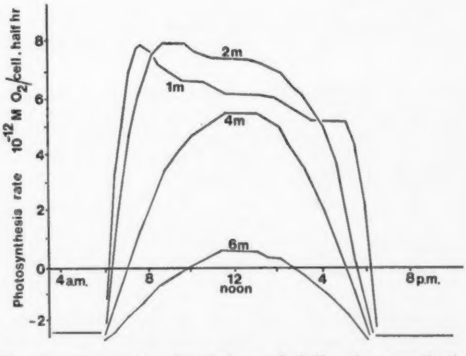

FIG. 5. Computer simulation of daily photosynthetic responses at 1–6 m. Static water column and cloudless conditions. This assumes extrapolation from Fig. 1 with no afternoon recovery.

sponses like Fig. 6 for cloudless days in the top 10 m (Fig. 3). Previous laboratory experiments (Harris and Lott 1973a) have showed that at high maximum intensities (1.2 ly/min equivalent to surface sun) recovery does not occur after noon but an asymmetrical curve similar to Fig. 5 is obtained. Respiration rates were, however, not measured in that study.

These facts would indicate a general pattern of daily production on cloudless, calm days as follows. At the surface, maximum rates are achieved before noon even as early as 8 AM (Fig. 3). Thereafter the photosynthesis rate declines as photoinhibition and photorespiration limit the overall rate. At depths of approximately 2–3 m recovery is possible after the noon depression due to the reduced light intensity experienced by the populations. At depths of 5 m or so the maximum intensity reached is never sufficient to cause photoinhibition and symmetrical photosynthetic responses occur. These conclusions are adequately borne out by the data in Table 1 (see Vollenweider and Nauwerck 1961).

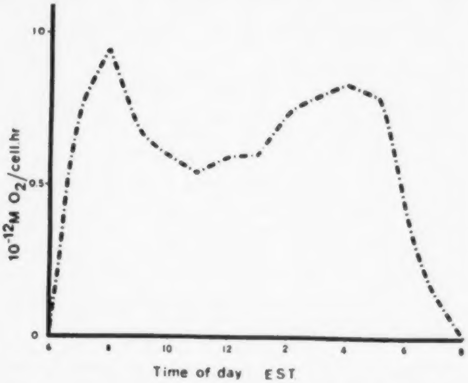

FIG. 6. Daily photosynthesis response on a cloudless day for the top 10 m sampled in April. Note the noon depression and the afternoon recovery. This curve was extrapolated from data in Fig. 1 and 3.

Vertical mixing by such mechanisms as Langmuir cells will complicate the issue as will light regimes other than perfectly cloudless days. A data base for simple models has, however, been achieved and further research will be required to fill in the many remaining gaps in our knowledge. The adaptive significance of the hysteresis effect appears to be associated with the lowered saturation light intensities of the populations and deep mixing in the lake. Apparently cells adapted to more efficient utilization of low light are in dynamic equilibrium with the surface light intensity. Physiological research needs to be done here.

SEASONAL PERIODICITY

The seasonal pattern of photosynthetic hysteresis responses (Fig. 7) shows systematic changes which at present cannot be attributed solely to either environmental or species effects. The hysteresis effect disappears during the summer and seems to be particularly associated with diatom populations.

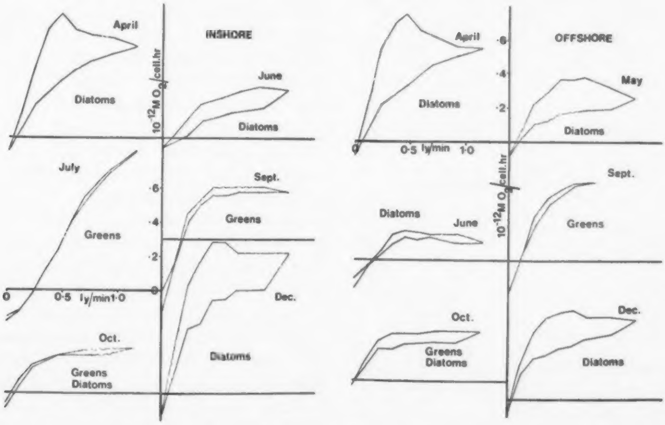

FIG. 7. The seasonal changes observed in the photosynthetic responses of the populations offshore (station 19) and inshore (station 11) 10:00 AM means. The curves give the photosynthesis rate for 50 sec at each intensity rising and falling.

Certainly the summer populations trapped in high light in the epilimnion are less susceptible to photoinhibition than the spring and winter populations which can be vertically mixed in an isothermal water column to remain at lower light levels. The inshore population in July is the most highly adapted to sun conditions (Fig. 7). Changes in the hysteresis effects at different times of the year and under different conditions may not be species dependent. On various cruises, pure populations of nannoplankton (<64 μ), diatoms, green algae, and blue green algae have been examined and all conformed to the pattern shown by the overall mixed population. This would indicate that changes in the hysteresis effect throughout the year are environmentally induced and that all species conform.

The return of the hysteresis effect in the fall and winter (Fig. 7) indicates that this type of physiological response may be adopted in response to lowering light intensities and an increasing mixing depth.

Plots of saturation light intensity and compensation point (Fig. 8A) showed that the saturation light intensity increases during the summer and declines again in winter, with the midlake populations changing more slowly and peaking later than the inshore populations. The compensation points in the inshore station showed a dramatic rise at the end of the summer and this can be associated with a corresponding rise in the respiration rate (Fig. 8B).

The seasonal cycle of respiration (Fig. 8B) showed a rise during the summer and a sharp drop in the fall which correlated with the seasonal temperature cycle. The inshore repiration rates rose faster than the offshore rates, perhaps reflecting the earlier warming of inshore waters (Fig. 9). The close relationship between water temperature and respiration rate is not surprising. Apparently (Fig. 9) the per cell respiration rate remains constant until a temperature of 8 C is reached and thereafter the rate rises with increasing temperature. The single high respiration value is that for September inshore where either the population was senescent or the

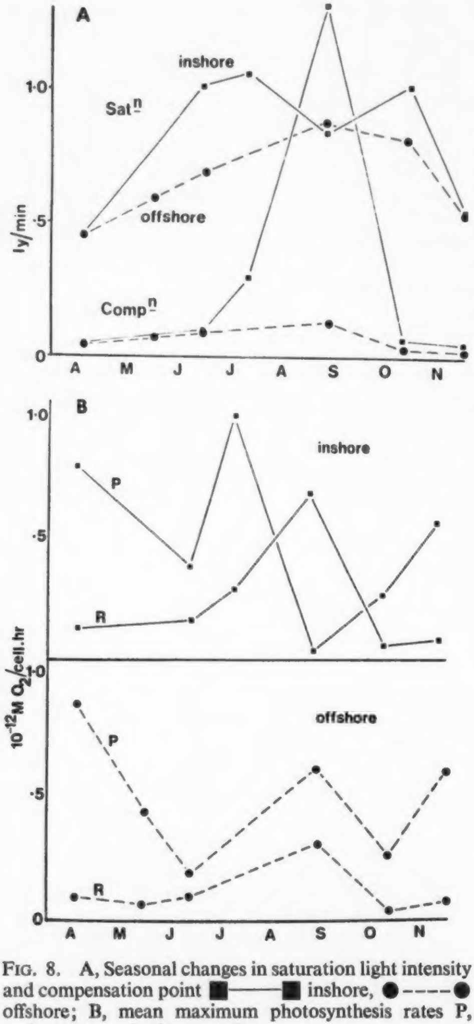

FIG. 8. A, Seasonal changes in saturation light intensity and compensation point ■——■ inshore, ●----● offshore; B, mean maximum photosynthesis rates P, and mean respiration rate R.

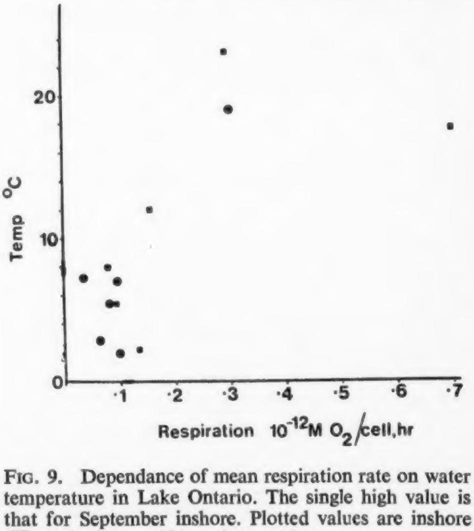

FIG. 9. Dependance of mean respiration rate on water temperature in Lake Ontario. The single high value is that for September inshore. Plotted values are inshore (■) and offshore (●) cruise grand means.

population was adversely affected by low soluble phosphorous concentrations.

The pattern of maximum photosynthesis rates during the year was more complicated. After a spring maximum there appeared to be an early summer low in photosynthesis on a per cell basis associated with the onset of stratification (around mid-June). As Nalewajko (1967) points out *Melosira* at least is relatively heavy and sinks out when stratification occurs. The removal of some diatoms by sinking and the photoinhibition of the rest by their entrapment at the surface in the epilimnion, may lead to their replacement by populations better adapted for growth at high light (see July populations Fig. 7).

The recovery in photosynthesis rates in July–September was faster inshore but the sharp drop inshore in September was associated both with a rise in respiration and nutrient depletion of the surface waters. Continued photosynthesis by nannoplankton at this time indicates either that the nannoplankton are better able to utilize available nutrients or that the net fraction populations are senescent. The subsequent recovery by inshore populations in October can be correlated with an improvement of the nutrient status of the surface waters (by mixing with the hypolimnion as the thermocline descends) and with the growth of a fall diatom population.

The midlake photosynthesis peak occurred later than at the lake edge. This may be associated with the earlier onset of warming and stratification at the edge. This midlake peak was terminated when the fall cooling had occurred.

Consideration of data such as these inevitably begs as many questions as it solves. Further work needs to be carried out in many areas before a clear indication of the many complex factors is obtained. A little is known (Nalewajko 1966, 1967; Munawar and Nauwerck 1971) about the distribution and numbers of species in the lake, sufficient merely to partially delimit the species succession and to show that the succession is widely different from year to year. It seems clear though that environmental changes dictate the physiological types observed and that both the light and temperature regimes are involved. Adaptation to light by the populations is affected by mixing both depth and water temperature, as extreme high light adaptation occurred at the time of maximum water temperatures 1 month after the radiation maximum. However, the basic rationale for this work was to obtain a data base or a lake production simulation model. Even a simple model using the above data will give a good first approximation to the real situation in the lake.

A correlation can be made between the mean maximum photosynthesis rate for each cruise and station and the rate of change of mean water temperature in the lake for each station at that time (Fig. 10). This does not necessarily indicate that the phytoplankton are sensitive to the rate of change of temperature per se as many environmental parameters are changing at the same time as the water temperature. It may indicate, however, that the photosynthetic capability of the cells is closely matched to the incident light intensity (Fig. 2 and 3) and is only slowly adapted to changing water temperatures. Once again research is needed here.

The relationship does, however, give us a predictive capacity for seasonal cycles (Fig. 11). By noting the rate of change of mean water temperature each month for the two stations (mean water temperature generated from cruise data 1960–68[2]) it is possible to interpolate between the cruise periods. The change in water temperature with time in the lake varies from year to year (Rodgers and Anderson 1963) and this will affect the production rates. However, we can estimate the entire annual cycle of photosynthesis in the lake. If this is done (Fig. 12) the data can be approximately converted to conform to a ^{14}C methodology by estimating the total number of cells present per milliliter. Multiplication of this number by the mean maximum

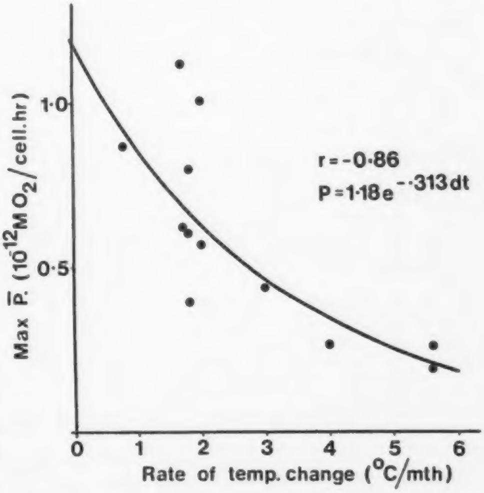

FIG. 10. Relationship between the mean maximum net photosynthesis rate for each station on each cruise and the mean rate of change of water temperature.

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[2] Data obtained by kind permission of the Canada Centre for Inland Waters.

rate per cell and converting to cubic meters gives us the production figures in units (mgO_2/m^3 per hr) which should be directly comparable to ^{14}C data (see Glooschenko et al. 1974). Cell numbers were estimated from Nalewajko (1966) and Munawar and Nauwerck (1971) converting the latter's inshore and offshore packed cell volumes to numbers by assuming that the average phytoplankton cell is a sphere 20 μ in diameter. The numbers generated agreed well with Nalewajko's (1966) cell counts. This assumption was made in the full knowledge that net phytoplankton do not constitute the entire producing biomass (Kalff 1972) and that the measured mean maximum rates may not apply to all species. The concern at this point was, however, to generate an annual cycle rather than to predict absolute rates of production.

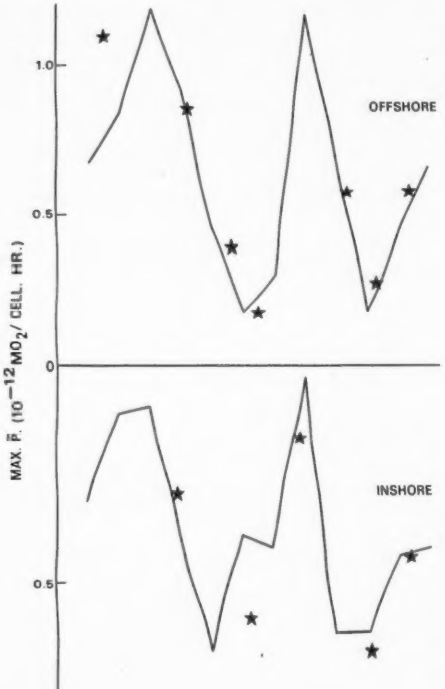

FIG. 11. A comparison of predicted (——) and observed (★) maximum photosynthesis rates. Mean water temperature data for stations 19 and 11 were smoothed and rates of change plotted. Mean maximal photosynthesis was generated by the equation of Fig. 10.

The annual cycle generated (Fig. 12) can be seen to reproduce well certain features known to occur in the lake. Firstly, production rates inshore consistently exceed offshore values except in the summer and early fall (Glooschenko et al. 1974). Secondly, there are two peaks of production in the year, spring and summer, a situation typical of mesotrophic lakes such as Lake Ontario. Thirdly, the summer peak starts first inshore and spreads towards the center of the lake.

To calculate production rates for the lake from these maximum rates we need to know how the photosynthetic characteristics of the populations change throughout the year (Fig. 7). We also need to know the effect of temperatures on respiration (Fig. 9). With a knowledge of how the cells are likely to be affected by water mixing (Fig. 7) we can attempt to calculate photosynthesis rates in relation to these variables at different times of the year. In short we can attempt to simulate the annual cycle of production in the lake. Actual rates of production by the net plankton will rarely, if ever, reach the maximum values as light and/or nutrients cannot be at the optimum for the entire population spread out vertically in the water column.

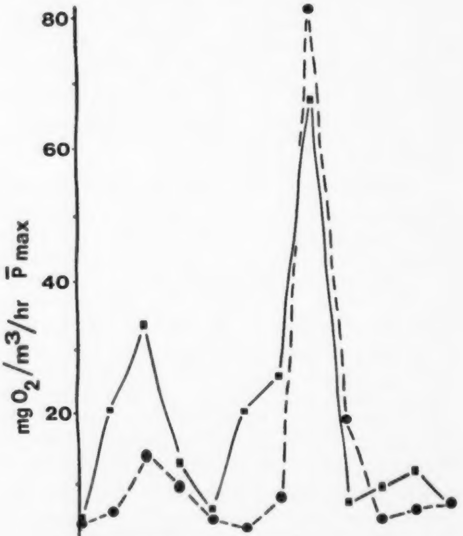

FIG. 12. Predicted seasonal changes in maximum photosynthesis rate. Maximum rates per cell have been transferred to mgO_2/m^3 hr by taking cell number data from Munawar and Nauwerck (1971). ■——■ inshore ●----● offshore.

Kalff (1972) estimates that nannoplankton contribute about 75% of the total production in a north temperate zone lake. The production estimates given here therefore should represent about one quarter of the production for Lake Ontario. By applying mixing to the computer model of Fig. 5, by moving the populations vertically in the water column, we estimated the effect of mixing on the daily photosynthetic total. It was found that when a population anchored at 1 m depth was compared to the same population mixed from 1-m to 6-m depth under the same light conditions, the photosynthetic daily total was reduced by 68% due to the lower light experienced by the populations when lower in the water column.

This work is being continued by the construction of a lake wide dynamically mixed model, relating temperature, mixing depth, wind speed, and surface light intensity.

Acknowledgments

I gratefully acknowledge the help and assistance given by many members of the Canada Centre for Inland Waters in Burlington. I particularly wish to thank Dr W. A. Glooschenko and the operations crew of the M.V. *Martin Karlsen*, also F. M. Boyce, M. Donelan, and D. Hore for their assistance with the Niagara barge project. Thanks also to my colleague, Dr J. Lott and to my technicians, C. Turner and R. Smith.

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Crawling and Respiration as Indices of Sublethal Effects of Oil and a Dispersant on an Intertidal Snail *Littorina littorea*

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Hargrave, B. T., and C. P. Newcombe. 1973. Crawling and respiration as indices of sublethal effects of oil and a dispersant on an intertidal snail *Littorina littorea*. J. Fish. Res. Board Can. 30: 1789–1792.

Crawling and respiration rates of the snail *Littorina littorea* are increased in the presence of Bunker C oil and decreased with brief exposure to a low toxicity dispersant (Corexit 8666) in sea water at 20 C. The addition of the dispersant to an oil:seawater mixture also decreases both crawling and respiration. Behavioral traits, such as crawling, and physiological indices, such as respiration, may be sensitive measures of sublethal effects of pollutants on organisms.

Hargrave, B. T., and C. P. Newcombe. 1973. Crawling and respiration as indices of sublethal effects of oil and a dispersant on an intertidal snail *Littorina littorea*. J. Fish. Res. Board Can. 30: 1789–1792.

Les taux de glissement et de respiration du bigorneau comestible, *Littorina littorea*, augmentent en présence d'huile lourde de type C et diminuent après courte exposition à un dispersif de faible toxicité (Corexit 8666) dans l'eau de mer à 20 C. L'addition du dispersif à un mélange huile:eau de mer ralentit également le glissement et la respiration. Certaines caractéristiques du comportement tel le glissement et des indices physiologiques telle la respiration peuvent être des indicateurs sensibles des effets sublétaux des agents de pollution sur les organismes.

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In a recent review of toxicity tests for aquatic organisms, Sprague (1971) concluded that changes in behavioral and physiological activity may serve as indicators of sublethal effects. Swedmark et al. (1971) have used changes in several behavioral patterns to assess invertebrate susceptibility to various surfactants. Sublethal effects due to these compounds could be quantified through changes in locomotor activity and respiratory movements in both fish and crustaceans. Metabolic rate and swimming activity in larval stages of the crab *Uca* both decreased in approximately parallel fashion after exposure to solutions containing sublethal amounts of $HgCl_2$ (DeCoursey and Vernberg 1972). Motor activity and respiration are obviously closely related and it appears that either may be used as an indicator of sublethal toxicity.

The present study indexes sublethal effects of oil and a low toxicity dispersant on an intertidal snail, *Littorina littorea*, by measurement of changes in crawling and respiration rates. Certain variables which might affect toxicity are considered in an attempt to assess the sensitivity of these measures of sublethal effects.

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Methods

Snails were collected from a rocky moderately exposed intertidal beach in Bedford Basin[1], Nova Scotia. All collections were made at the same tide level (2 m) during winter and early spring when water temperature ranged from −0.5 to 5.0 C. Snails were immediately placed in 4–5 C or 18 C aerated water from the sampling site and held 1–2 hr before the start of experiments.

Sea water from the collection site was mixed by high speed rotary mixer with either crude Bunker C oil (50 ml/liter mixed 90 min), with the oil dispersant Corexit 8666 (10 ml/liter mixed 2 min), or with an emulsion of oil and dispersant (mixed 2 min). Resulting solutions were poured through a coarse cloth to remove oil not emulsified in the water. Final concentrations of oil in water measured in hexane extracts on a fluorescence spectrophotometer (excitation 310 nm, emission 374 nm) ranged from 750–800 μg/liter. No fluorescing material passed a 0.45-μ pore diameter membrane filter and thus oil must have existed in suspension as finely dispersed particles. No measure of dispersant concentrations achieved by mixing was attempted.

Groups of 50 snails sorted to approximately the same size by shell height were placed in 500-ml aerated samples of the sea water prepared with oil, dispersant, or oil: dispersant emulsion. Control groups were held in untreated sea water. After either 30-min or 24-hr exposure snails were rinsed and transferred to a series of cylinders or flasks which contained untreated sea water. In some experiments transfer was to sea water containing the same oil, dispersant or oil:dispersant mixture and thus snails were continuously exposed to various treatments.

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[1] A small marine bay (17 km^2 surface area) separated from the sea by Halifax Harbour. Oil concentrations in surface water range from 2–10 μg/liter.

Nine 1-liter cylinders with five snails per cylinder were used for each determination of crawling rate. The vertical distance moved by each snail every 5 min was recorded for 30 min. No attempt was made to measure actual path length crawled, but most of the movement was vertical and for comparative purposes linear distance was most easily determined. Total distance moved each 5 min was divided by 45 to calculate the total distance crawled per individual (Fig. 1). Rate of movement could be calculated from linear regression curves comparing total distance crawled and time.

Some measure of variability in rates of crawling and respiration determined within groups of snails collected on different dates was necessary before differences induced by treatments could be evaluated. Time course curves used to derive mean crawling rates could not be compared for an estimate of variance within groups of snails since mean values were calculated for distances crawled at fixed time intervals. Thus, several experiments were conducted where individual crawling rates were measured for treated and untreated snails on three different dates.

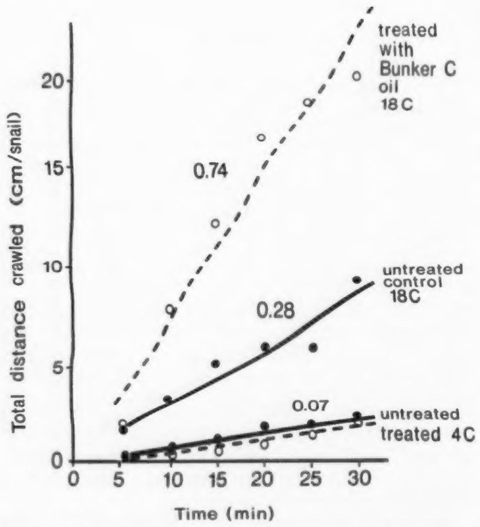

FIG. 1. Average upward distance crawled by five snails, *Littorina littorea*, with and without preexposure to oil saturated sea water. Values adjacent to lines indicate slope coefficients (crawling rate, cm/min) of calculated regression lines.

Oxygen uptake by single snails in 30-ml glass-stoppered flasks was measured over 4 hr at 4 and 18 C. A Radiometer Blood Gas Analyzer was used to measure dissolved oxygen in control (blank) and experimental flasks. Oxygen concentrations were never reduced more than 15% during experiments. Oxygen uptake by 25–30 snails of various sizes was measured for each treatment or control series all of which were carried out in duplicate.

Results

There was considerable variation in crawling rates determined on different dates, but Corexit exposure always lowered crawling activity most with continuous exposure (Table 1). There was no consistent effect of animal size on crawling rate and variation averaged ±30% for all treatments.

Crawling rates of *Littorina* at 4 C were so low that differences induced by treatments were difficult to detect (Table 2). Significant effects were more clearly demonstrated in experiments conducted at 18 C. Crawling rates were significantly lowered after brief or continuous exposure to Corexit. Bunker C oil stimulated crawling only with continuous exposure and the oil:dispersant emulsion depressed crawling rates also only with continuous treatment.

Respiration rates were determined for individual snails and thus slopes and intercept constants of regression lines could be compared by a *t*-test (Fig. 2, Table 3). Confidence limits ranged from 10–15% of mean slope values for all treatments and there was no significant difference in slopes of

TABLE 1. Average crawling rates for groups (15) of *Littorina littorea* (18 C) determined from individual measurements made on different occasions with and without exposure to Corexit. V = coefficient of variation $\left(\frac{\sigma}{\bar{x}}\cdot 100\right)$.

Treatment		Avg crawling rate (*cm/min*)	σ	V
Untreated	Nov.	0.96	0.14	0.15
	May	0.65	0.19	0.29
	July	0.40	0.10	0.25
Corexit (30-min) exposure	Nov.	0.48	0.14	0.30
	May	0.58	0.21	0.36
	July	0.25	0.10	0.39
Corexit (continuous) exposure	Nov.	0.07	0.02	0.29
	May	0.03	0.01	0.33
	July	0.05	0.02	0.40

TABLE 2. Crawling rate of *L. littorea* exposed to various treatments at two temperatures.

Treatment and exposure	4 C		18 C	
	cm/snail/min	% change	cm/snail/min	% change
Corexit 8666				
untreated	0.08	-	0.71	-
30 min	0.08	0	0.40*	-43
continuous	0.04*	-50	0.07*	-90
Bunker C				
untreated	0.07	-	0.28	-
30 min	0.06	-14	0.36	+28
24 hr	0.05	-28	0.36	+28
continuous	0.10*	+43	0.39*	+39
Bunker C:Corexit 8666				
untreated	0.09	-	0.42	-
30 min	0.06	-33	0.32	-24
continuous	0.03*	-67	0.03*	-93

*Significantly different ($P<0.05$) from control by *t*-test (8 df)

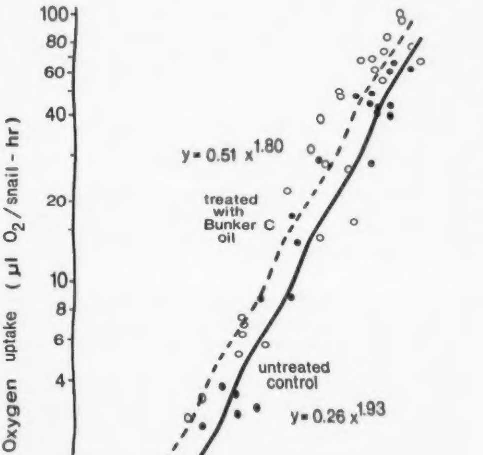

FIG. 2. Oxygen consumption by various sizes of the snail *L. littorea* in untreated sea water (18 C) with and without 30-min preexposure to sea water saturated with Bunker C oil. Slopes of the lines are similar ($P<0.05$) but the *y*-intercept value is significantly increased by brief exposure to oil.

regression lines. Thus, there was no size-specific effect of various treatments. However, intercept values were altered by exposure to oil and to the dispersant and for comparison rates of oxygen uptake were calculated for snails of 15-mm shell height.

Significant differences in respiration (20.9 ± 2.5 μliters O_2/animal/hr, 15-mm she llheight) could not be measured at 4 C for any treatment. Exposure to Corexit or the emulsion at 18 C, however, significantly reduced oxygen uptake by

TABLE 3. Changes in respiration and crawling rate of *L. littorea* as percent of controls (untreated) after 30-min preexposure to three treatments at 18 C.

Treatment	% change over control[a]	
	Oxygen uptake (*μliters O_2/animal/hr*)	Crawling rate (*cm/animal/min*)
Corexit 8666	-36	-43
Bunker C oil	+34	+28
Corexit: Bunker C mixture	-48	-24

[a] Absolute values for crawling rates in Table 2; for oxygen uptake, 50.2 ± 5 μliters O_2/animal/hr.

Littorina, whereas exposure to Bunker C oil increased it (Table 3). Thus both crawling and respiration rates were altered in a similar way for a particular treatment, but the magnitude of the effect was not always equivalent. For example, the emulsion had the least effect on crawling and the greatest effect on respiration.

Snails kept in flowing sea water after several experiments fed and crawled normally. On two occasions when respiration was measured after 3 months, there was no significant difference from control animals collected simultaneously but held without treatment.

Discussion

Both crawling activity and oxygen consumption of *Littorina* can be altered by brief exposure to sublethal concentrations of oil and the dispersant Corexit 8666. On a percentage basis Corexit depressed crawling and respiration rates more than oil stimulated these parameters and the effects increased with continuous exposure (Table 2). The high toxicity of oil dispersants in contrast to oil has been well documented for both plants (Brown 1972) and invertebrates (Corner et al. 1968; George 1971). Although Corexit 8666 may be of low toxicity, its effect on *Littorina's* behavior and respiration conforms to the general response of many invertebrates to surface active agents (Swedmark et al. 1971).

Sprague (1971) has summarized previous studies which attempt to use changes in respiration or locomotor activity as a measure of toxicity. He stresses that variability in rates of oxygen uptake is a major difficulty, particularly for fish where activity markedly alters oxygen consumption. This problem is not as severe with invertebrates such as *Littorina* where there may be less difference between basal and active metabolism. Also, even if normal respiratory rates are altered by confinement, the effect of a treatment may still be assessed by comparison with a control.

Of the two indices of sublethal toxicity considered in this study, respiration is the more sensitive. Greater variability in crawling rates (± 30%) may have been due, in part, to experimental design. Upward movement in cylinders was undoubtedly a stress response. Control animals always moved up continuously and eventually would crawl through the surface film and out of the cylinders. Also, there was often a delay in the initiation of crawling as a result of introducing snails to cylinders. No attempt was made to quantify this response but the delay was longest after treatments with dispersant or emulsion. It contributed substantially to reduced crawling rates under these conditions.

Since crawling and respiration rates were determined at 4 and 18 C, Q_{10} values could be calculated and compared. There was no effect of treatment but mean Q_{10} values for crawling (3.0 ± 0.77) were significantly higher than values (1.7 ± 0.51) derived from respiration measurements. Presumably the sublethal effects indexed are not associated with marked changes in metabolic processes. This would explain the lack of a size effect with various treatments; small snails were not affected to a greater degree despite higher metabolism per unit weight. On the other hand, significant differences did exist between Q_{10} values calculated for respiration and crawling. This and the observed differences in response to a particular treatment as indexed by the two methods (Table 3) indicate that under the experimental conditions crawling behavior and oxygen uptake are not quantitatively related.

No attempt was made to use changes in rates of crawling and oxygen uptake as quantitative measures of toxicity. Short exposure periods and large temperature changes would not allow snails to acclimate to laboratory conditions and thus results cannot be interpreted on a physiological basis. These measures are useful as qualitative indices of toxic effects. With adequate controls and sufficient replicates to establish some measure of variance, the methods affort simple yet sensitive indicators of sublethal toxicity.

Acknowledgments

Mrs G. Phillips and Mr R. Branton provided assistance with some experiments. Imperial Oil of Canada Ltd., Dartmouth, N.S., supplied samples of Bunker C oil and the dispersant Corexit 8666.

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Distribution of *Udonella caligorum* Johnston, 1835 (Monogenea: Udonellidae) on *Caligus elongatus* Nordmann, 1832 (Copepoda: Caligidae)

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KABATA, Z. 1973. Distribution of *Udonella caligorum* Johnston, 1835 (Monogenea: Udonellidae) on *Caligus elongatus* Nordmann, 1832 (Copepoda: Caligidae). J. Fish. Res. Board Can. 30: 1793–1798.

A large number (2933) of *Caligus elongatus* (Copepoda: Caligidae) removed from the buccal cavities of cod, *Gadus morhua*, off the west coast of Scotland, were examined for presence and distribution of *Udonella caligorum* (Monogenea: Udonellidae). Distribution of worms was not consonant with space available for attachment. Eggs and young worms were found primarily on the posterior half of the copepod, whereas adults occupied predominantly the lateral margins of the cephalothoracic shield. It was concluded that *U. caligorum* has a feeding area and a nursery area on the copepod and carries out migrations between them. Location of the feeding area strongly suggests that the worm feeds directly on the epithelial tissues of the fish.

KABATA, Z. 1973. Distribution of *Udonella caligorum* Johnston, 1835 (Monogenea: Udonellidae) on *Caligus elongatus* Nordmann, 1832 (Copepoda: Caligidae). J. Fish. Res. Board Can. 30: 1793–1798.

Nous avons examiné un grand nombre (2933) de *Caligus elongatus* (Copepoda: Caligidae) prélevés de la cavité buccale de la morue franche, *Gadus morhua*, au large de la côte occidentale d'Ecosse, en vue d'établir la présence et la répartition d'*Udonella caligorum* (Monogenea: Udonellidae). La répartition des vers n'a pas de rapport avec l'espace disponible pour la fixation. Les oeufs et les jeunes vers se trouvent surtout sur la moitié postérieure du copépode, alors que les adultes occupent en grande partie les bords latéraux de la carapace du céphalothorax. Nous en concluons que *U. caligorum* a une aire d'alimentation et une aire d'élevage sur le copépode, et qu'il y a migrations entre les deux aires. L'emplacement de l'aire d'alimentation suggère fortement que le ver se nourrit directement des tissus épithéliaux du poisson.

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Udonella caligorum Johnston, 1835, is a monogenean fluke with a controversial systematic position and some unique features in its life history. It was originally placed in a separate family, Udonellidae Taschenberg, 1879, to be upgraded later to a superfamilial status Udonelloidea Yamaguti, 1963, or even to be assigned to a new class Udonelloidea, Ivanov 1952. *U. caligorum* has no free-swimming dispersal stage, its larvae hatching as miniature adults. It lives attached to surfaces of copepods parasitic on fishes, mainly copepods of the family Caligidae, though sometimes to others only remotely related to the caligids.

Information on the biology of *U. caligorum* is scanty, though the worm was studied in vivo by Sproston (1946) and was a subject of a monograph by Ivanov (1952). These two and earlier authors accepted *U. caligorum* as an epizoic fluke feeding on debris of fish tissues damaged by the activity of the copepod. This conclusion was prompted mainly by indirect evidence provided by observations on distribution of the worm on the copepod. Sproston (1946), in particular, states that the worm spends most of its life on the posterior half of the copepod, or on its ventral side. The copepod is believed to feed by scraping off superficial tissues of the fish and to push some of the debris backwards along its ventral surface by vigorous movements of its appendages. The worm is, therefore, located in the right place for intercepting its food.

This view, however, is based on assumptions not entirely supported by other investigations. A survey of the literature dealing with this topic produces a confused picture, summed up in a paper by Causey (1961). There are conflicting reports as to the distribution of *U. caligorum* upon its caligid carriers, some favoring the view that the egg sacs are the site preferred by the worm, others suggesting that

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surfaces of the body itself are more frequently inhabited. All are based on rather scanty data.

The matter is of some interest to those who are concerned with possible deleterious effects of parasites on their host fishes. If *U. caligorum* is not a harmless fellow-traveller subsisting on macerated tissues, as suggested by earlier writers, then it must obtain its food directly from the fish. Should this be the case, then the presence of the worm might aggravate the damage caused by the copepod.

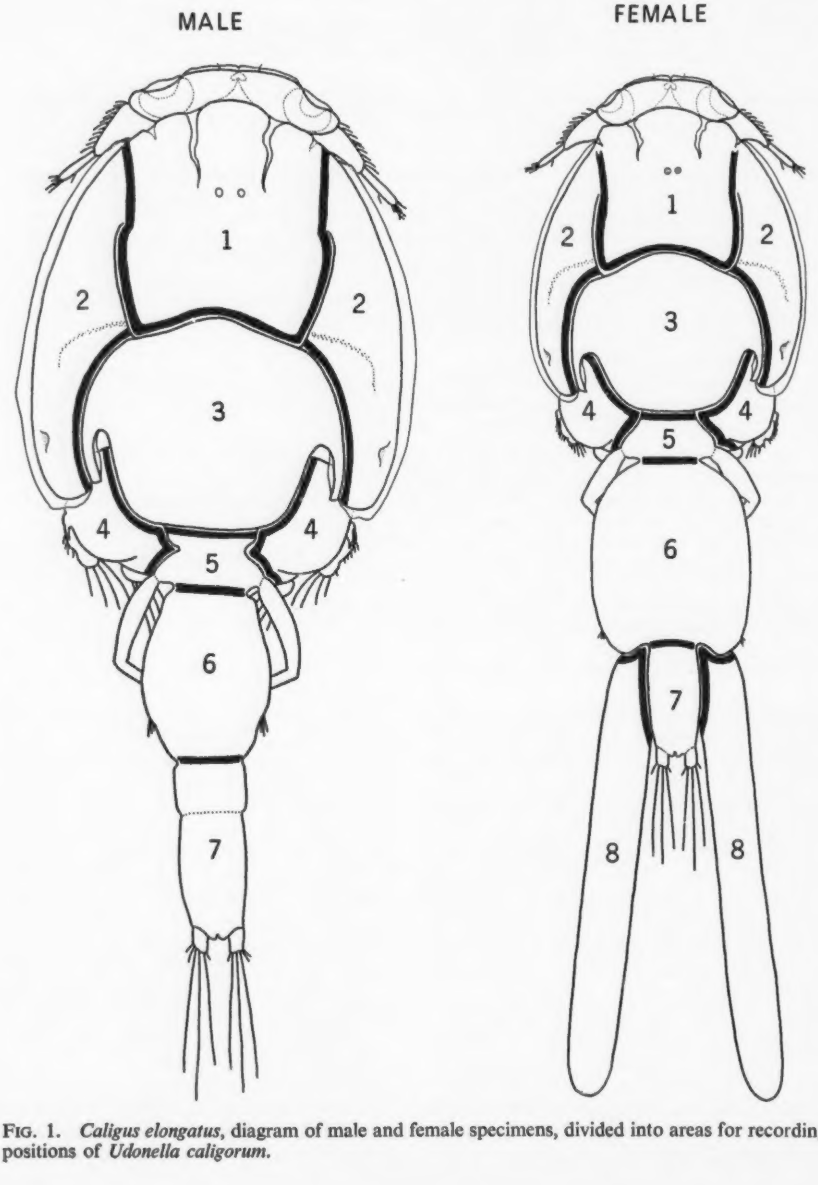

FIG. 1. *Caligus elongatus*, diagram of male and female specimens, divided into areas for recording positions of *Udonella caligorum*.

Circumstantial evidence from the distribution of the worm on the copepod can be used to gain insight into the nature of the relationship between *U. caligorum* and the fish parasitized by the copepod on which it lives. This paper presents new data on this distribution and discusses their implications.

Materials and Methods

During research cruises of F.R.S. *Explorer* of the Marine Laboratory, Aberdeen, Scotland, in 1964 and 1965, *C. elongatus* was collected from the buccal cavities of Atlantic cod, *Gadus morhua*, along the west coast of Scotland. Each specimen of *C. elongatus* was measured (total length and dimensions of each tagma). The numbers and position of mature and immature *U. caligorum*, as well as position of its egg clusters, were noted. (Condition of the gonads was used as a criterion for assigning worms to mature or immature group.) For the purpose of recording these positions, the surface of the copepod was divided into areas, as shown in Fig. 1. Area 1 corresponds to the cephalic zone of the dorsal shield of the cephalothorax (Parker et al. 1968); right and left lateral zones are designated as area 2 and the thoracic zone as area 3. The flat third legs projecting from beneath the posterior end of the dorsal shield are labelled area 4 and the fourth leg-bearing segment area 5. The genital complex is referred to as area 6 and the abdomen as area 7. The egg sacs of the female are marked area 8. In each area three positions are recognized: dorsal, ventral, and marginal. The last-named is a narrow strip along the free margins of an area. All counts and measurements were made under a dissection microscope in a standard manner by the same observer (Mr A. D. Campbell, Freshwater Fisheries Laboratory, Pitlochry, Scotland). In all, 2933 specimens of *C. elongatus* (2599 females and 334 males) were examined. Positions of 11,797 worms and 2611 egg clusters were recorded.

Results

The examined population of *Caligus* was heavily populated by *Udonella caligorum*. In all, 74.3% of the females and 40.7% of the males carried various numbers of worms. The average burden was 5.8 per infected female and 2.3 per infected male. Average number of egg clusters was 1.3 per infected female and 0.3 per infected male. Distribution of worms and egg clusters is tabulated separately for male and female copepods.

Table 1 shows that on the female copepods about three-quarters of the worm population is concentrated in area 2, notably along the lateral margins of the dorsal shield. Areas 2 and 3 combined accounted for 81.6% of all worms carried by female *C. elongatus*. On the male copepods (Table 2) the corresponding areas carried 68.1% of all the worms present, being, as in the female, the most heavily occupied region of the copepod. The posterior half of the body (genital complex, abdomen, and egg sacs, i.e. areas 6, 7, and 8) harbored only about 14% of the worms on female copepods and about 24% on the males. The egg sacs, however, carried only 3.6% of the total population of worms.

Of the 3123 immature worms found on the female (Table 3), about one-third was found in area 2, mainly in a marginal position. A similar proportion of the immature worm population occurred on the posterior half of the body (areas 6–8). Of 106 immature worms occurring on the males (Table 4), about half were in areas 2 and 3 and half on the posterior half of the body (areas 6 and 7).

The distribution of egg clusters is quite different. Most of those found on the female copepods (Table 5) were attached to the posterior half of the body (90.8%). Males carried only 42 clusters, 31 of which were on the genital complex and abdomen (Table 6). On the whole, data obtained from the female cannot be easily compared with those gained from the male

TABLE 1. Distribution of *Udonella caligorum* (mature and immature) on female *Caligus elongatus*. (Unbracketed figures are numbers of worms; figures in brackets denote percentage of totals.)

Area	Dorsal	Ventral	Marginal	Total
1	96	12	60	168(1.5)
2	30	5	8380	8415(73.2)
3	35	4	927	966(8.4)
4	185	–	16	201(1.7)
5	19	2	113	134(1.2)
6	31	177	220	428(3.7)
7	52	510	192	754(6.6)
8	398	5	18	421(3.6)
Totals	847(7.4)	715(6.2)	9926(86.4)	11,487(100.0)

TABLE 2. Distribution of *U. caligorum* (mature and immature) on male *C. elongatus*. (Unbracketed figures are numbers of worms; figures in brackets denote percentages of totals.)

Area	Dorsal	Ventral	Marginal	Total
1	–	–	–	–
2	1	–	139	140(45.2)
3	–	1	70	71(22.9)
4	12	–	–	12(3.9)
5	2	–	10	12(3.9)
6	12	1	11	24(7.7)
7	32	3	16	51(16.4)
Totals	59(19.0)	5(1.6)	246(79.3)	310(100.0)

copepods, due to the great disparity in numbers and differences in overall size and proportions of the body between the two sexes. It can be said, however, allowing for this fact, that the figures from the males are roughly similar to those from the females.

Discussion

The distribution of *U. caligorum* on its copepod carrier is not consonant with the amount of space available. Almost three out of every four worms carried by the female copepods are crowded along the lateral margins of the dorsal shield. The distribution of the immature worms is somewhat different, whereas that of the egg clusters is completely unlike that of either the total worm population or of immature worms.

Only a very small proportion of worms carried by the female copepods (about 6%) was attached to the ventral surface, where — as we were told by earlier writers — the debris of fish tissue destroyed by the copepod is available for them as food. The posterior half of the body also harbors a small proportion of worms (about 14%). Only one out of five worms was found attached to those areas of the copepod body on which the worms could make good use of tissue debris. The obvious site of predilection, the marginal position of area 2, clearly gives to its occupants the least chance to get at such debris. On the other hand, worms attached there have easy access to the epidermis of the buccal cavity of the fish.

The suggestion (Sproston 1946) that *U. caligorum* might feed on the remnants of copepod meals was based on Russell's (1925) description of the attachment behavior of a copepodid of *Caligus pageti* Russell, 1925 (Russell's "metanauplius"). Scraping activity referred to by Russell is, in fact, the excavation of an implantation cavity in which the copepod places the terminal plug of its frontal filament. When feeding, all species of *Caligus* and related

TABLE 3. Distribution of immature *U. caligorum* on female *C. elongatus*. (Unbracketed figures are numbers of worms; figures in brackets denote percentage of totals.)

Area	Dorsal	Ventral	Marginal	Total
1	6	2	5	13(0.4)
2	12	1	1137	1150(36.8)
3	19	–	609	628(20.1)
4	72	–	8	80(2.6)
5	15	–	56	71(2.3)
6	14	117	119	250(8.0)
7	42	366	162	570(18.2)
8	342	4	15	361(11.6)
Totals	522(16.7)	490(15.7)	2111(67.7)	3123(100.0)

TABLE 4. Distribution of immature *U. caligorum* on male *C. elongatus*. (Unbracketed figures are numbers of worms; figures in brackets denote percentages of totals.)

Area	Dorsal	Ventral	Marginal	Total
1	–	–	–	–
2	1	–	13	14(13.2)
3	–	–	34	34(32.1)
4	6	–	–	6(5.7)
5	1	–	7	8(7.5)
6	11	–	5	16(15.1)
7	22	–	6	28(26.4)
Totals	41(38.7)	–	65(61.3)	106(100.0)

TABLE 5. Distribution of *U. caligorum* egg clusters on female *C. elongatus*. (Unbracketed figures are numbers of egg clusters; figures in brackets denote percentages of total egg clusters.)

Area	Dorsal	Ventral	Marginal	Total
1	–	–	1	1(0.03)
2	4	–	49	53(2.0)
3	3	–	75	78(3.0)
4	6	–	–	6(0.2)
5	4	–	94	98(3.8)
6	10	1100	767	1877(73.1)
7	36	292	122	450(17.5)
8	6	–	–	6(0.2)
Totals	69(2.7)	1392(54.2)	1108(43.1)	2569(100.0)

TABLE 6. Distribution of *U. caligorum* egg clusters on male *C. elongatus*. (Unbracketed figures are numbers of eggs clusters; figures in brackets denote percentages of total egg clusters.)

Area	Dorsal	Ventral	Marginal	Total
1	–	–	–	–
2	–	–	1	1(2.4)
3	–	2	3	5(11.9)
4	–	–	–	–
5	–	–	5	5(11.9)
6	2	7	11	20(47.6)
7	4	3	4	11(26.2)
Totals	6(14.0)	12(28.6)	24(57.1)	42(100.0)

genera apply their mouths closely to the skin or buccal epidermis of the fish, sealing the orifice with a ring of marginal membrane. Any fragments of tissue rasped off the surface are taken up directly into the mouth cone. Small amounts could escape, when the cone is detached at the end of a meal, but they would hardly be sufficient to sustain a population of worms. It can be presumed, therefore, that *U. caligorum* browses actively on the superficial tissues of the fish and that feeding on tissue debris, if it occurs, can be only of secondary importance.

In view of the fact that the majority of worms congregate in area 2, the posterior distribution of egg clusters, commented upon by earlier writers and confirmed by the present data, suggests that some movements of worms over the surface of the copepod must take place. One can postulate that a more or less uniform migration of mature worms from the dorsal shield to the genital complex area occurs immediately prior to the time of oviposition. The ability of *U. caligorum* to perform it has been established by earlier writers (e.g. Sproston 1946). It is more difficult to discover the reasons for a selective site on which eggs are deposited. The genital complex and abdomen of *Caligus* are raised above the surface of the fish, when the latter is in motion. Suspended in midwater, they are bathed on all sides by the current, unlike any other part of the copepod. Possibly, conditions created by this uninterrupted flow are optimal for the processes of development and hatching.

On hatching, the young worm attaches itself to the copepod in the vicinity of the permanently anchored egg from which it has emerged. Sproston (1946), who found that the eggs were almost always attached to the genital complex, observed that on hatching, the young worms "immediately sought the shelter of the carapace." It would appear that she caught a glimpse of the forward migration of the immature worms to the marginal position in area 2. The suggestion that they move towards the ventral side of the cephalothorax could be attributed to the small number of worms observed. The fact that hatching occurs on the surface of the posterior half of the copepod means that the worm population in that area must contain more immature individuals. Tables 3 and 4 show that about one-third of all immature worms on the female and about 40% on the male copepods are found in that area (compared with corresponding figures for the total population of 14 and 24%, respectively).

In brief, the data in Tables 1–6 suggest that: (i) *U. caligorum* feeds actively on the superficial tissues of the fish; (ii) it performs migrations over the surface of the copepod with definite biological aims; (iii) the lateral margins of the shield are a favorite "feeding position" of the worm, whereas the posterior half of the body is a "nursery position."

The conclusions prompted by the examination of data provided by Tables 1–4 leave unanswered the problem of the transfer of *U. caligorum* from copepod to copepod and from fish to fish. For the former transfer, a direct contact between copepods appears necessary. Such contact is frequent on even large fish hosts, particularly when infections are heavy (as many as 200 *C. elongatus* were found in a buccal cavity of a single cod). As for the fish-to-fish dispersal, Ivanov (1952), prompted by the statement of Dawes (1946) that hatching of *U. caligorum* is synchronous with that of the copepod, suggested a possibility of the young worms attaching themselves to the free-swimming larvae of *Caligus*. This suggestion cannot be accepted for the following reasons. The newly hatched worm and the nauplius are of about the same size, the former being about 325–420 μ long (Schell 1972), the latter from 430 to 500 μ (Kabata 1972). Moreover, only a few worms occur on the egg sacs, from which the nauplii hatch. Before the copepod settles on a new host, the free-swimming stage involves two moults that would present insurmountable difficulties for the transfer of the worm. It is more probable that an adult *Caligus* transports *U. caligorum* when it changes its hosts. Such changes were suggested by Kabata and Hewitt (1971). This possibility is also suggested by repeated finds of free-swimming *C. elongatus* (cf. Thompson 1889; Scott 1891; Gadd 1904; Wilson 1905; etc.).

Acknowledgments

I wish to express my thanks to Mr A. D. Campbell (Freshwater Fisheries Laboratory, Pitlochry, Scotland), who took great pains in measuring *Caligus* and recording *Udonella*.

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Energy Expenditure of Sockeye Salmon, *Oncorhynchus nerka*, During Sustained Performance

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Brett, J. R. 1973. Energy expenditure of sockeye salmon, *Oncorhynchus nerka*, during sustained performance. J. Fish. Res. Board Can. 30: 1799–1809.

Fingerling and adult sockeye salmon (*Oncorhynchus nerka*) were subjected to long periods of sustained swimming (10–20 days) in air-saturated fresh water. Energy expended was computed from change in body composition and compared with the metabolic equivalent from multiple determinations of oxygen-consumption rate. Caloric loss from body substance exceeded that estimated from total oxygen uptake by an average of 19.8%. The reasons for the difference, and the assumptions involved, are discussed. The difference apparently arises from slight excretion of partially metabolized fuels (anaerobic metabolism) and loss from sloughed body tissues. An oxycalorific equivalent of 4.8 kcal/liter O_2 is considered an acceptable value for fish.

Brett, J. R. 1973. Energy expenditure of sockeye salmon, *Oncorhynchus nerka*, during sustained performance. J. Fish. Res. Board Can. 30: 1799–1809.

Nous avons soumis des alevins et des adultes de saumon nerka (*Oncorhynchus nerka*) à de longues périodes de nage soutenue (10–20 jours) dans de l'eau douce saturée d'air. Nous avons mesuré l'énergie dépensée à partir des changements de composition du corps et l'avons comparée à l'équivalent métabolique obtenu à la suite de plusieurs déterminations du taux de consommation d'oxygène. Les pertes caloriques de la substance corporelle dépassent de 19.8% en moyenne celles estimées à partir de l'absorption d'oxygène total. Nous discutons des facteurs responsables de cette différence, ainsi que des hypothèses impliquées. Nous concluons que la différence est due apparemment à une légère excrétion de carburants partiellement métabolisés (métabolisme anaérobie) et à une perte causée par le dépouillement des tissus corporels. Un équivalent oxycalorifique de 4.8 kcal/litres O_2 est considéré comme acceptable pour les poissons.

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The propulsive power of fish, or the rate of expending energy, has usually been measured by determining the rate of oxygen consumption at various levels of activity. Until recently, it has been assumed that in the presence of adequate oxygen the respiratory metabolic rate could be converted into caloric units of energy by applying the oxycalorific equivalent[1] derived for homeotherms (Brody 1945; Kleiber 1961). Winberg (1956) considered that only a slight improvement in accuracy could be obtained by determining the N-free respiratory quotient, which would permit assessing the relative contribution of carbohydrate, fat, and protein to the oxidative release of energy. That fish are not necessarily bound to balance their energy expenditure aerobically was shown by Blazka (1958) in the unusual case of the Crucian carp, *Carassius carassius*, which overwinters in shallow ponds completely devoid of oxygen. The little-understood phenomenon a of anaerobiosis in fish is discussed by Hochachka and Somero (1971).

The oxycalorific assumption for fish was virtually shattered by Krueger et al. (1968) who examined the depletion of lipids and fatty acids in young coho salmon when swimming to exhaustion. Caloric losses estimated from projected oxygen-consumption rates were only one-third of the actual losses calculated from lipid metabolism. Some of the difference was attributed to the duration and severity of the exercise, but in the main the error was ascribed to evaluating heat production indirectly from O_2 consumption when large quantities of partially oxidized metabolic products are accumulated or excreted.

With a view to assessing the possibility of error in the method of indirect calorimetry when applied

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[1] For every liter of oxygen respired approximately 4.8 kcal are expended when the respiratory quotient = 0.80.

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to sustained performance of fish, experiments were begun in 1965 to continuously track the oxygen consumption of fingerling sockeye salmon when forced to swim a sufficient distance that would significantly reduce their body constituents. A comparison of the two methods of determining energy expenditure was proposed — caloric loss calculated from oxygen consumption vs. that from loss of body substance. Some difficulties arose from insufficiency in the proximate analyses first performed, necessitating extending the study. This earlier work, supplemented in 1969 by more extensive studies including experiments on adult sockeye salmon, is reported herewith.

Materials and Methods

Two distinct sizes of sockeye were used: 2-year-old fingerlings from freshwater cultured stock, and silvery 4- or 5-year-old adults just entering fresh water from the sea 2 months prior to spawning. Experiments on the small fish were conducted in a 23-liter tunnel respirometer; those on the adult fish in an exercising cage, and in an 110-liter respirometer.

Fingerling Sockeye

A sample of 25 fish of uniform size was selected (see Table 1). After 3 weeks at 15 C they were starved for 72 hr and then randomly divided into five groups of five fish. One group was lightly anesthetized, measured, and weighed (free of surface moisture), and put in the 23-liter respirometer. Each of the other four groups was treated similarly for comparison, then killed, reweighed, and stored at -15 C. This provided a measure of the starting wet weight of the fish to be exercised, and a control sample for estimating their composition at zero time.

The respirometer was an expanded version of the 13-liter unit described earlier (Brett 1964). It can be operated on open or closed circuit, maintaining a high accuracy of controlled temperature and uniform velocity. On open circuit, flushing-water maintains oxygen saturation. At any time, oxygen consumption can be checked by switching to closed circuit and determining the rate of oxygen depletion. During the 1st day in the respirometer, following recovery from light anesthetic, the velocity was gradually raised in steps to about one-half the maximum cruising speed. Oxygen samples were taken every 2 hr for the first 8 hr. Each day thereafter the metabolic rate was checked daily, usually at 0800, 1200, 1600, and 2300 hr, and less frequently at 0400 hr, until terminating. the test on the 18th day in the first (1965) experiment, and on the 20th day in the second (1969) experiment. On one occasion during the 2nd week of the 1969 test, oxygen-consumption rates were determined every 1½ hr throughout 24 hr to assess the representative nature of the limited routine observations.

On the last day of the 1965 test, the critical swimming speed was determined by raising the velocity in steps of approximately 0.5 L/sec[2] (9.1 cm/sec or 0.3 ft/sec) each hour until fatigue of the first fish was observed. At this point the respirometer was turned off, the five fish killed, reweighed, and stored at -15 C.

Adult Sockeye

The capture, handling, and imposition of forced, prolonged exercise on adult salmon was a difficult task. Problems of injury, infection, outbursts of aggression, excitability, and exceptional hydrodynamic sensitivity required the development of special techniques. Because of additional problems created by some of the secondary sexual characteristics of the male (e.g. elongated snout, sharp maxillary teeth), and the greater biological energy demand placed on the female to elaborate a large ovary (average = 12% of dry body weight) preselection for females was practised. In the late silvery stage, the selection was about 70% accurate.

The test apparatus consisted of a streamlined, exercise cage placed in a long flume (Fig. 1). Within the flume a false bottom was built in the form of an inclined plane rising from an upstream depth of 2.4 m (8 ft) to a terminal depth of 1.2 m (4 ft). Water entering the flume at 0.6 m/sec (2 ft/sec) accelerated to 1.2 m/sec (4 ft/sec) at the shallow downstream end, and was further increased in velocity by a converging intake on the exercising cage to provide a maximum velocity of 1.7 m/sec (5.5 ft/sec). The cage was mounted on rollers so that any desired velocity within the possible range could be obtained simply by moving it forward or backward thereby altering the amount of water directed through the cage. The fish were confined in a rectangular section (2 m wide, 2 m long, 0.7 m high) with a plexiglass top.

Strips of plexiglass (0.2 m wide) were set lengthwise along all four inside edges at an angle of 45° to exclude areas of slightly reduced velocity. At the downstream end an electrified vertical "louvre screen" was cyclicly charged with 8 v (60 cycle, AC) for approximately 2 sec every minute. This conditioned the fish to avoid the screen while reducing the chances of contacting a series of charged louvres by periodic sideways sweeps along the electrodes — with devastating consequences.

In 2 succeeding years, migrating salmon were captured in the Great Central Lake fishway (Vancouver Island, B.C.) in early July during a peak in the upstream migration, and transported at 5 C to the flume. The low temperature mildly anesthetized the fish, facilitating the sexing and selection of injury-free fish, which were transferred to two plastic holding tanks. A "zero-time" sample (unexercised controls) was killed and frozen on site after lengths and weights had been taken. After the remaining fish had been treated with 1.5% NaCl and 1:10,000 2-phenoxyethanol as a prophylaxis, they were lightly anesthetized with M.S. 222 and placed in the exercising cage. The velocities in the cage were increased gradually over 6 hr to 0.83 m/sec (2.7 ft/sec).

On the last day of each test the surviving fish were killed, weighed, measured, and frozen for subsequent proximate analysis.

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[2] Stands for total body lengths/sec, as applied by Bainbridge 1960.

TABLE 1. Mean sizes and body composition (per fish) recorded for preexercised, control (killed at starting time), and exercised fish (killed at finish). Fat, protein, and caloric content expressed on a dry weight basis. Significant differences determined by Student's *t*-test.

	Preexercised			Controls				Exercised				Difference		
	n	Mean	± 2 SE	*n*	Mean	± 2 SE	Body fraction (%)	*n*	Mean	± 2 SE	Body fraction (%)	Signif. (*p*-value)	Amt/fish (*g*)	Amt/fish (%)
1965 test														
Total length (*cm*)	5	19.5	0.08	20	19.6	0.11	–	5	19.7	0.10	–	n.s.[d]	–	–
Wet weight (*g*)	5	74.46	1.33	20	75.95	1.27	–	5	65.37	1.57	–	<0.01[b]	9.09	12.2
Dry weight (*g*)	–	19.2[a]	–	20	19.62	0.16	25.7	5	13.80	0.12	21.1	<0.01[c]	5.4	28.1
Water (*g*)	–	55.3[a]	–	11	56.33	0.42	74.2	3	51.85	0.36	78.9	–	–	–
Calories (*kcal*)	–	–	–	12	5.77[e]	–	–	3	5.38[e]	–	–	–	–	–
1969 test														
Total length (*cm*)	5	13.2	0.38	20	13.1	0.42	–	5	13.1	0.38	–	n.s.[d]	–	–
Wet weight (*g*)	5	16.89	1.47	20	16.63	0.96	–	5	14.21	1.40	–	<0.01[b]	2.68	15.9
Dry weight (*g*)	–	3.8[a]	–	20	3.74	0.13	22.5	5	2.21	0.22	17.8	<0.01[c]	1.53	40.9
Water (*g*)	–	13.1[a]	–	20	12.89	0.31	77.5	5	12.00	0.28	82.2	<0.01[c]	0.89	6.9
Fat (*g*)	–	–	–	20	0.602	0.088	3.6	5	0.232	0.032	1.6	<0.01[c]	0.37	61.5
Protein (*g*)	–	–	–	20	2.56	0.114	15.4	5	2.05	0.096	14.0	<0.05[c]	0.51	19.9
Calories (*kcal*)	–	–	–	20	5.77	–	–	5	5.38	–	–	–	–	–

[a] Determined by applying value from controls.

[b] Comparison made between preexercised and exercised.

[c] Comparison made between controls and exercised.

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Using a larger respirometer with an 18-cm diameter plexiglass tunnel, similar in basic design to the model for fingerling fish (see Bell and Terhune 1970), oxygen-consumption rates were determined in relation to performance (Brett and Glass 1973). These permitted estimates of the metabolic rate of the adult salmon performing in the exercising cage.

PROXIMATE ANALYSIS AND CALORIMETRY

Each fish (and adult ovary) was ground to a fine homogenate. Weighed fractions were used to determine water, fat, and protein content in duplicate by the following methods:

Water — Approximately half the subsample was oven-dried at 105 C for 24 hr. A correction for any moisture loss during deep-freezing was applied.

Protein — Nitrogen was determined by the Kjeldahl method outlined by the Association of Official Analytical Chemists (AOAC 1960). The value was multiplied by 6.25 to obtain the average protein content. This could introduce some error if only one or a few proteins were involved. However, for the large variety making up the whole organism the average value of 16% N is considered suitable (Love 1970).

Fat — Lipid analyses were first performed by the chloroform–methanol wet extraction technique of Folch et al. (1957). A small error may occur from the carry-over of moisture, but would not exceed more than 10% of the total lipid estimate. In 1969 this was changed to exhaustive hexane extraction (method of T. D. D. Groves, described in Appendix B in Brett et al. 1969; see also Groves 1970).

Carbohydrate — No analysis of carbohydrate was conducted because this constituent does not amount to more than 0.3% body weight (Vinogradov 1953; Black 1958; Dean and Goodnight 1964). Highest content occurs in the liver where values from 3 to 4% have been obtained for normal feeding fish (Hochachka and Sinclair 1962).

Ash — Determined in a furnace at 750 C.

Calorimetry — Caloric values were either determined with a Parr bomb calorimeter (methods prescribed by the American Society for Testing Materials 1966) or calculated from proximate analysis using values of 9.45 kcal/g for fat and 5.65 kcal/g for protein (Brody 1945; Kleiber 1961). Where physiological equivalents were determined, a value of 4.60 kcal/g was used for protein.

The 1965 analyses were performed by a commercial laboratory. An error in following instructions on subsampling resulted in greatly reduced statistical sensitivity (see Results). Subsequently all determinations on young sockeye were conducted by the Department of Biochemistry, University of Victoria.

Results

FINGERLING SOCKEYE

Performance — In the 1965 test, following the introductory day, the fingerlings swam at an imposed velocity of 39.6 cm/sec (2.02 L/sec) for 5 days, and at 30.5 cm/sec (1.57 L/sec) for the next 11 days. The reduction in swimming speed was introduced because of concern that one of the five fish might collapse prior to the desired performance time, disrupting the whole experiment. However, on the last day (18th), it was possible to see what sort of reserve capacity remained after continually swimming for a distance of approximately 530 km (330 miles). Using velocity increments of 5.1 cm/sec per hour the velocity was raised until the first fish showed onset of fatigue; this occurred at 49 cm/sec (2.5 L/sec). The velocity was then immediately reduced to avoid any possible damage to the fish. The expected mean critical speed is 75 cm/sec for this size and temperature (Brett 1965, 1967). However, the variance is such that the first fish of five would be expected to succumb at about 55 cm/sec. Apparently little loss in performance capacity had occurred.

In the 1969 test, an initial velocity of 16.5 cm/sec (1.25 L/sec) was imposed with the thought of subsequently increasing it to the higher velocity of the 1965 test. Fairly heavy aggression commenced in this group, elevating oxygen consumption, so it was decided not to alter the velocity. By the 15th day the velocity accidentally rose (probably from a voltage surge) to 18.3 cm/sec. No further change occurred up to termination on the 20th day.

Oxygen consumption — The daily records of oxygen uptake for both tests showed high consumption rates during the first 12 hr (Fig. 2). This resulted from the excitement of being introduced into the respirometer, staged increases in velocity, and initial interaction between the five fish. By the 14th hr in the 1965 test a relatively steady state existed that continued with few exceptions up to the last day when the performance capacity was checked. The total oxygen consumption determined from daily computations was 18.8 liters O_2.

By contrast the 1969 experiment was plagued with repeated aggressive acts and territorial defense. This lasted most of the time, passing through a low intensity period (9th–14th day), breaking out with renewed intensity (15th–17th day), and settling down to least severity in the last 3 days. Total oxygen consumption by this group of relatively smaller fish was 4.86 liters O_2.

The mean metabolic rates (± 2 SE) during steady periods are shown in Fig. 2 along with the expected

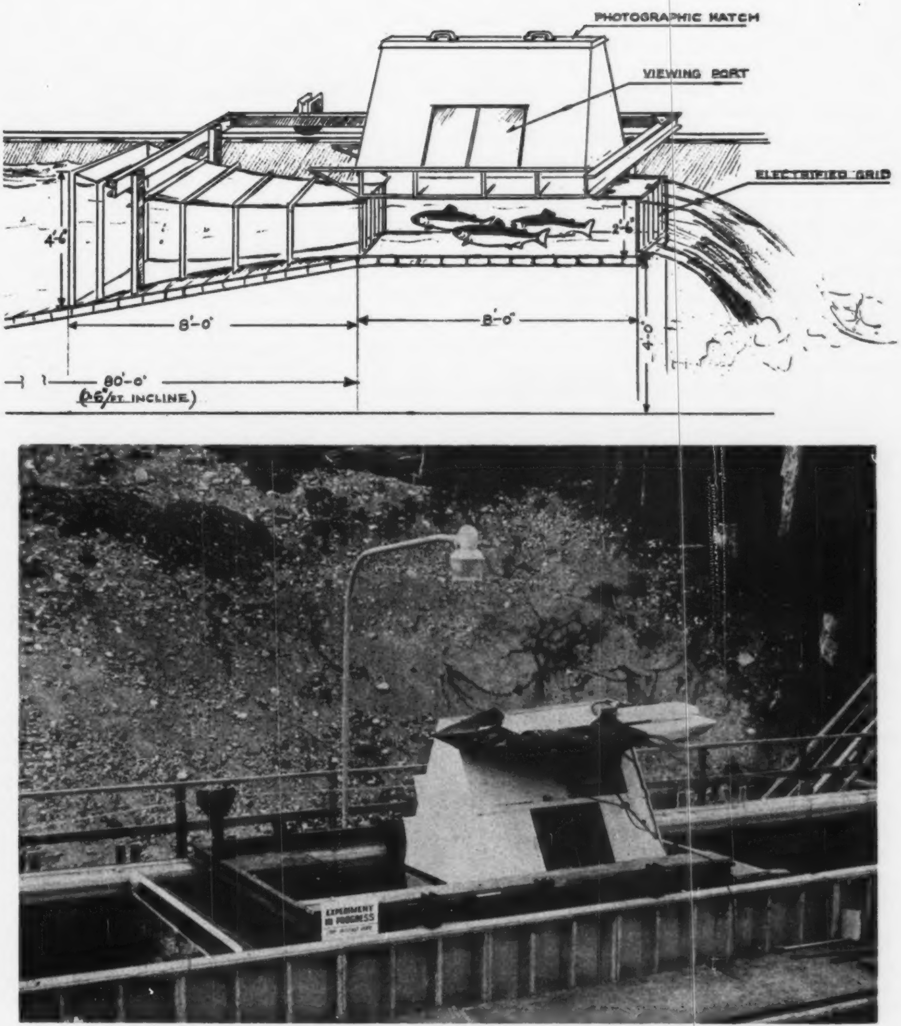
PHOTOGRAPHIC HATCH
VIEWING PORT
ELECTRIFIED GRID
4'-6"
2'-6"
8'-0"
8'-0"
4'-0"
80'-0"
(0.6"/FT INCLINE)
EXPERIMENT IN PROGRESS

FIG. 1. (*Upper*) Cut-away view of mobile exercising cage for adult salmon, suspended from an iron frame mounted on wheels on the side of an 80-ft long flume. The cage is in the extreme downstream position in the flume, with the bottom touching the inclined plane. In this position all water is directed through the cage, producing maximum velocity. Dimensions in feet (1 ft = 0.31 m). (*Lower*) Side view of exercising cage at operating water-level in the flume. Black plastic curtain raised to show viewing-port and electrical control panel.

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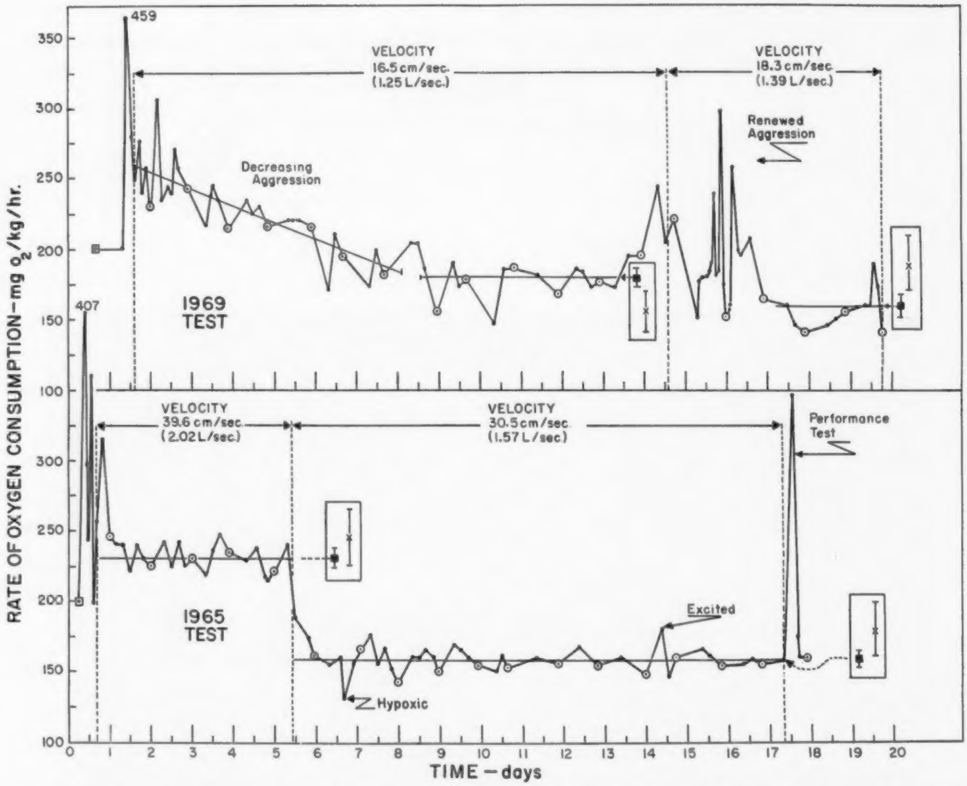

Fig. 2. Daily records of rate of oxygen consumption of fingerling sockeye salmon in a tunnel respirometer at 15 C. The last record on each day is circled. Imposed velocities are indicated. Mean rates (± 2 SE) are indicated (squares) for periods of steady performance and compared with mean rates (crosses) previously obtained with 36-hr starved fish tested singly (Brett 1964). On the 18th day of the 1965 experiment the velocity was raised to check performance capacity. Changing states of aggression are indicated in the 1969 experiment.

rates for the particular velocity, size, and temperature determined previously for "standard" 36-hr starved fish (Brett 1964). The mean values for the prolonged exercise group are lower by 12% in the three cases[3] where the fish performed steadily without complication from bursts of aggression. Starvation is the likely cause of this small reduction in metabolic rate.

As the period from midnight to 0800 hr was assumed to be characterized by a mean metabolic rate derived mainly from observations taken during the balance of the day, a series of readings was made every hour over 24 hr on the 15th day during the 1969 test. The mean rates for records taken in the day (0800–2400 hr) and at night (0000–0800 hr) were, respectively, 191.4 ± 20 mg O_2/kg/hr ($n = 7$) and 190.6 ± 32 mg O_2/kg/hr ($n = 13$). Obviously no significant difference occurred. The physical conditions in the respirometer did not vary with time of day (continuous lighting, controlled velocity, and temperature, etc.), therefore any possible endogenous rhythm was apparently overridden.

TABLE 2. Basic data on fish sizes, speeds, times, and expected metabolic rates used to compute total oxygen consumed by exercised adult sockeye salmon (*Oncorhynchus nerka*).

	Group 1	Group 2
Total length (*cm*)	55.1	47.9
Wet weight[a] (*g*)	1969	1615
Temperature ± range (*C*)	13±1.2	18±1.4
Applied velocity (*cm/sec*)	65.2	77.8
Duration (*hr*)	240	336
Total distance (*km*)	563	934
Standard metabolic rate (*mg O_2/kg/hr*)	45	62
Active " " (" " " ")	680	725
Derived[b] " " (" " " ")	160	220
Total O_2 consumed (*liters*)	72.2	116
Energy expended[c] (*kcal*)	347	562

[a] Mean of the starting and final weights.
[b] By applying techniques developed in Brett and Glass 1973.
[c] Using a caloric equivalent of 4.8 kcal/liter O_2.

Weight change, proximate analysis, and energy expended — The total wet weight loss of the 1965 fingerlings was 45.45 g or 12.2% of the starting weight; that for the 1969 test was 13.43 g or 15.9% of the starting weight (Table 1). No distinctive marking was used so it was impossible to be sure of the weight loss for any particular fish except in the case of the one distinguishably large fish among the five used in 1969 (15.5% loss). The variability in weight loss was greater among the 1969 group which displayed so much interaction; the smallest fish apparently lost 19.9% wet weight.

An error in the 1965 sampling procedure for proximate analysis (replicated fat and protein determinations were done on different fish rather than the same fish), and an apparent error in the fat determinations (thought to have carried moisture over in some of the hexane extraction) reduced the confidence in these data; only the reliable dry weight measurements were retained (Table 1).

By assuming a mean caloric value from the 1969 determinations (Table 2) an estimate of the energy expended by the five fish can be calculated as follows:

Loss in dry body weight = 27.0 g
Caloric content = 5.57 kcal/g
Metabolizable fraction[4] (physiological value) = 0.8
Energy expended = 27.0 × 5.57 × 0.80 = 120.4 kcal

The body composition of the 1969 exercised fish showed significant changes in all major components (Table 1). The moisture content rose from a mean of 77.5% to 82.2%. The fat content per fish dropped from 0.602 g (3.6%) to 0.232 g (1.6%) representing a 62% depletion, whereas protein was only 20% reduced — from 2.56 g (15.4%) to 2.05 g (14.0%). Of the total energy expended 60% was derived from lipid sources, as determined below:

Energy from fat utilization
= 0.37 × 5 × 9.45 = 17.49 kcal
Energy from protein utilization
= 0.51 × 5 × 4.60 = 11.73 kcal

Energy expended (tolal) = 29.22 kcal

ADULT SOCKEYE

Performance — In the first successful operation of the exercising cage (Group 1) only four female fish were analyzed from each of the exercised and nonexercised samples. It was considered a useful full-scale preliminary test, after 3 years of development. As it turned out the final test in the following year (Group 2) was not as successful as hoped. Of the 20 fish starting the prolonged exercise, only 11 survived; the losses resulted mainly from technical difficulties. Of the 11, eight were females.

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[3] When compared by use of Student's *t*-test the probability values are 0.3, 0.03, and 0.01.

[4] Assumes that the available energy from body fuels is 80%, the balance being lost in excretion (particularly ammonia and urea).

Group 1 swam at a mean velocity of 65.2 cm/sec (2.14 ft/sec; approx 1.2 L/sec) for 10 days. This is equivalent to a distance of 563 km (350 miles). The swimming speed was just under one-half the maximum 1-hr sustained speed. The ambient temperature ranged from 12 to 14 C.

Group 2 swam at a mean velocity of 77.8 cm/sec (2.55 ft/sec; approx 1.8 L/sec) for 14 days, covering 933 km (580 miles) at temperatures ranging from 17 to 19 C. This speed is almost one-half the maximum 1-hr sustained speed.

Oxygen consumption — As stated earlier no concurrent measurements of oxygen consumption could be made in the large flume. However, from respirometer results, it is possible to deduce the requirements for the appropriate speeds, times, and temperatures (Table 2) (Brett and Glass 1973). These are minimal, insofar as the oxygen consumption rates relate only to locomotion costs and not to aggressive acts or other additional costs of excitement. Although aggression undoubtedly enters into the exercising relation, the occurrence of such extraneous acts was not observed to be frequent even though they were intense on occasion.

The total oxygen consumption per fish computed for the two cases was 72.2 liter O_2 (Group 1) and 116 liters O_2 (Group 2); the equivalent in heat would be 347 kcal and 562 kcal, respectively.

Weight change, proximate analysis, and energy expended — Because the adult fish experienced some mortalities during exercise, and also were not distinctively marked, the deduced weight of the surviving exercised fish at starting time had to be determined by applying a correction to the zero-time sample (controls) according to the slight length differences (Table 3).

In both groups there was a highly significant increase in moisture content of the exercised fish, accompanied by a significant decrease in lipid, protein, and caloric content per gram of wet weight (Table 3). Only in the gonads of Group 2 salmon was there a significant decrease in moisture with a concomitant increase in lipid. Consequently in this latter group it was necessary to correct for diversion of energy into the gonad, separate from that expended in swimming. The calculations of energy utilized are as follows:

Group 1:

Dry weight change per fish =111.2 g (18.4% loss). No significant change occurred in the composition or caloric content of the dry weights of the controls and exercised fish, therefore the mean caloric value (5.29 kcal/g, Table 3) was applied.

Energy loss (product) = 588 kcal/fish/10 days
= 29.9 kcal/kg/day

The physiological caloric equivalent, using the reduced protein caloric value from Kleiber 1961 (4.60 kcal/g) becomes 4.78 kcal/g, according to the lipid/protein ratio utilized by the fish.

Metabolic heat produced = 532 kcal/fish/10 days
= 27.0 kcal/kg/day

Group 2:

Significant changes were recorded both in composition and gonad development, hence a somewhat different calculation is involved.

Total body change:

Caloric content of fish at start = 3068 kcal
Caloric content of fish at finish = 2426 kcal
Total caloric change (decrease) = 642 kcal

Gonad change:

Caloric content of ovary at start = 173 kcal
Caloric content of ovary at finish = 209 kcal
Gonad coloric change (increase) = 36 kcal
∴ Energy loss (difference) = 606 kcal/fish/14 days
= 26.9 kcal/kg/day

Adjusting for physiological values as in Group 1,

Metabolic heat produced = 545 kcal/fish/14 days
= 24.1 kcal/kg/day

To compare the foregoing results in a concise way the energy expended by each set of fish has been expressed in terms of kcal/kg/hr, as determined for each of the two ways of assessment. It is assumed that the body-loss determinations reflect the energy expended more accurately than the oxygen-consumption records. Consequently, the difference is calculated as a percentage of the body-loss figure.

Fish	O_2 consumed *(kcal/kg/hr)*	Body loss *(kcal/kg/hr)*	Difference *(%)*
Fingerlings			
1965	0.646	0.862	+25
1969	0.673	0.845	+20
Adults			
Group I	0.739	1.130	+35
Group II	1.017	1.003	–01
Mean difference			= 19.8

Discussion and Conclusions

ASSUMPTIONS AND SOURCES OF ERROR

The major assumptions which have been made relate to equating measures of oxygen consumption and determinations of loss of body substance to a common unit of energy — calories. Application of the standard heat equivalents is based either on total oxidation of the basic fuels (as in oxycalorific equivalents) or on the physiological equivalents of the metabolized fuels, derived for homeotherms

TABLE 3. Length, weight, proximate analysis, and caloric content of the zero-time (controls) and exercised adult salmon (± 2 SE). Significant differences between "zero-time" and "exercised" fish determined by Student's *t*-test.

	Group 1			Group 2		
	Zero-time	Exercised	Significance	Zero-time	Exercised	Significance
No. of fish (♀)	4	4	(*p*-value)	8	8	(*p*-value)
Standard length (*cm*)	49.0±1.5	49.3±2.7	>0.05	43.1±0.4	42.9±0.05	>0.05
Total weight (*g*)	2046±97	1879±299	>0.05	1682±84	1555±91	>0.05
Gonad weight (*g*)	255±43	260±47	>0.05	60±14	68±13	>0.05
Body moisture (%)	70.7±0.5	73.8±0.7	<0.01	68.3±1.5	70.8±0.9	<0.01
Body lipid (*% wet*)	8.7±0.4	7.6±0.5	<0.05	9.27±0.96	7.55±1.04	<0.01
Body nitrogen (*% wet*)	3.07±0.11	2.75±0.04	<0.01	3.28±0.32	2.91±0.17	<0.05
Body protein (*% wet*)	19.2±0.69	17.2±0.25	<0.01	20.5±2.0	18.2±1.1	<0.01
Body total energy (*kcal/g/wet*)	1.56±0.04	1.41±0.06	<0.01	1.83±0.12	1.56±0.09	<0.01
Body lipid (*% dry*)	29.8±1.0	29.2±1.7	>0.05	30.7±3.1	25.9±4.2	<0.05
Body protein (*% dry*)	65.5 –	67.2 –	–	64.7 –	62.4 –	–
Body total energy (*kcal/g/dry*)	5.18±0.18	5.39±0.18	>0.05	5.77 –	5.34 –	–
Gonad moisture (%)	57.5±1.1	58.7±0.9	>0.05	57.7±0.3	55.2±0.3	<0.01
Gonad lipid (*% wet*)	–	–	–	21.1±1.5	23.3±1.7	<0.05
Gonad nitrogen (*% wet*)	3.94±0.25	3.99±0.12	>0.05	3.46±0.69	3.43±0.43	>0.05
Gonad protein (*% wet*)	24.6 –	24.8 –	–	21.6 –	21.3 –	–
Gonad (*kcal/g/wet*)	–	–	–	2.88 –	3.07 –	–
Gonad lipid (*% dry*)	–	–	–	49.9 –	51.8 –	–
Gonad (*kcal/g/dry*	–	–	–	6.81 –	6.91 –	–

(mammalian caloric values). The energy equivalents can be applied only if the system is totally aerobic, and is essentially similar to the physiology of higher vertebrates. Conversely, the extent to which the salmon energetics is either anaerobic or physiologically different, or both, will be revealed to a large extent by the disparity between the two derived energy expenditures.

Oxygen consumption equivalent — The oxycalorific equivalent applied assumed an average respiratory quotient (RQ) of 0.8, a value which implies a normal balance in the sources[5] from which energy is derived. No respiratory quotients of salmon were determined. Kutty (1968) measured the RQ of rainbow trout (*Salmo gairdneri*) during spontaneous and forced activity (1.6 L/sec; 15 C). A mean RQ value of 1.2 occurred during the 1st hr of exercise followed by a relatively steady state of 0.85 during the 3rd–10th hr. Although noting that accurate measurement of CO_2 excretion is not without difficulties, Kutty (1968) concluded that the source of energy expended in steady swimming was entirely aerobic. Further studies by Kutty (1972) on the RQ of *Tilapia mossambica* support the general conclusion that, like most vertebrates, high RQs (above 1.0) characterize excessive exercise and excitement, usually for a brief period following commencement of activity. Fish, however, appear to maintain an RQ close to 1.0 for at least a number of hours following the start of exercise. This indicates a predominant carbohydrate energy source in the initial phase during which lactic acid is accumulated and excreted. Karuppannan and Kutty (unpublished data) reported a maximum rate of 60 mg lactate/kg/hr in the 1st hr of swimming for *Tilapia*, falling to a minimum of 10 mg/kg/hr by the 5th hr. Mearns (1970) in a study of lactic acid regulation in three species of salmonids recorded a maximum excretion rate of only 0.2 mg/kg/hr following activity, and concluded that loss of lactate through the urine represented about 0.1% of the active metabolic rate.

For the various groups of exercised salmon some loss of energy through anaerobic metabolism, involving lactate excretion, must have accompanied the early period of activity. Also small flurries of excitement as they undoubtedly occurred throughout the performance would contribute to this energy loss, unaccounted for by any record of oxygen consumption.

In regard to protein katabolism, the main excretory product for fish is ammonia, which is frequently cited as accounting for 65–70% of the nitrogenous wastes (Wood 1958; From 1963; Forster and Goldstein 1969).

Very few records have been made of the daily excretion of ammonia, particularly for fish in the postabsorbative state (12–24 hr starvation or longer). Kutty (1972) reported that ammonia-N excretion in *Tilapia* increased steadily from 36 ml/kg/hr in the 1st hr of exercise to 113 ml/kg/hr by the 6th and final hour of the experiment. This indicates a relatively high use of protein in long-term performance, an observation which is supported by energy studies of Idler and Clemens (1959) on the upstream spawning migration of Pacific salmon. The oxycalorific equivalent for protein metabolism in mammals is 4.46 kcal/liter O_2. Because ammonia represents a higher state of protein degradation than urea, with a greater energy yield, a value of approximately 4.6 kcal/liter O_2 would be more appropriate (calculated from Brody 1945; Lehninger 1965). The heat production of fasting domestic animals katabolizing only fat and protein is reported by Kleiber (1961) to require 4.7–4.8 kcal/liter O_2.

An oxycalorific value of 5.0 kcal/liter O_2 likely characterized the first day of the exercise period, but a value of 4.8, as used, is more appropriate for the whole period. If the former value prevailed the observed difference in average energy expenditure would be reduced from approximately 19% to 15% — obviously the bulk of difference recorded cannot be ascribed to this source.

Body fuels — physiological equivalents — Although metabolizable carbohydrates would be present in sufficient quantity in the liver to provide energy for the initial phase of prolonged exercise, in the case of a starving animal fat and protein are the major fuel sources. As recorded (Table 1 and 3) fat accounted for 60% of the energy expended by the 1969 fingerlings and 79% by calculation for the Group II adults. Under fully aerobic metabolism there is no difference between the physical and physiological caloric values of fat since the biodegraded end-products are both CO_2 and H_2O. Protein katabolism, however, results in a variety of degradable excreta of which the main components (and their approximate relative proportions) are: ammonia (70%), urea (15%)[6], amines[7] (5% est.), other (10%). The protein fraction of unused energy lost by each of these components is: ammonia (14.2%), urea (15.6%), amines (22%), other (20% est.). On this basis the physiological heat equivalent for protein in fish computes to approximately 15% less than the physical value, i.e. 5.65 × 0.85 kcal/g = 4.81 kcal/g. This is within 5% of the value commonly used for higher vertebrates.

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[5] $RQ = \frac{CO_2 \text{ produced}}{O_2 \text{ consumed}} = 1.0$ for carbohydrate, 0.71 for fat, and 0.81 for mixed protein (Blaxter 1965).

[6] Proportion of N-excretion, relative to ammonia, measured for 36-hr starved sockeye fingerlings in our laboratory by C. Zala in 1971.

[7] Mostly as trimethylamine oxide (Forster and Goldstein 1969). Traces of nine different amines were identified by Kleerekoper and Mogensen (1959).

Other body losses — Dry weight change of a starving animal is not accounted for solely by respiratory and urinary excretions. The secretion of mucus, the general sloughing of epidermal tissues (including scales), the replacement of blood cells, and the production of gastric fluid and fecal matter during starvation constitute losses which are not part of any energy computation based on oxygen consumption. Herein lies a source of difference that was not measured and which is difficult to assess.

In the absence of a complete accounting of all body losses the mean recorded difference of 19.8% between the "fuel calories" and "oxygen calories" could be accounted for by initial excretion of lactate coupled with a daily secreted or sloughed loss of about 0.5–1% of dry body substance per day.

Some underestimation of "oxygen calories" could have occurred for the adult salmon through lack of any accounting for metabolic elevation from excitement. In addition the 95% confidence limits for metabolic rate determinations for small samples are about ± 15% (see records of SE for standard and active rates in Brett 1964).

Consequently, there is no reason to conclude that major anaerobic losses occur for fish swimming actively for prolonged periods, any more so than for the marathon athlete who may finish his performance with a burst of speed. The general standards of energy equivalents developed for higher vertebrates apply with equal confidence to lower vertebrates — insofar as salmon can be considered a representative species.

KRUEGER'S ASSUMPTIONS

In the study of metabolic changes of coho salmon subjected to "severe and very severe muscular activity" conducted by Krueger et al. (1968) the fish were first conditioned to the exercising chamber at a low velocity for 20 hr, then subjected to an intermediate velocity for 1 hr, and finally forced to swim at a borderline fatigue velocity[8] for a maximum of 24 hr, or less if they fatigued (58% of sample). The amounts and changes in lipids and fatty acids were analyzed, comparing control (unexercised) and exercised samples. Saturated fatty acids accounted for about one-quarter of the total loss in fatty acids.

From measurements of wet weights of "controls" (exercised fish were not preweighed) and the information on lipids, estimates of the water, protein, and carbohydrate losses were made, providing a measure of total caloric loss. For comparison the authors then computed the expected oxygen consumption of the exercised coho by applying the rates of oxygen consumption determined by Brett (1964, 1965) for sockeye salmon, for comparable weight, speed and time (temperature unspecified). They concluded that the "caloric costs as estimated from material losses are three times the losses calculated from the O_2-consumption data." While pointing out that "differences between species and possible errors in materials... could account for some of the differences" it was further concluded that "even gross errors cannot account for all of the difference."

It is necessary to examine the assumptions which were made and critically evaluate the basis for the differences deduced so that the possible presence of substantially different energetic "balances" characterizing fish distinct from other vertebrates can be substantiated or not. The paper questions the confidence that can be placed in the use of the standard oxycalorific equivalents.

Application of oxygen consumption rates — Krueger et al. (1968) assumed that the minimum oxygen consumption rates (locomotor demand only) required for the first 20 hr of swimming at 8 cm/sec (1 L/sec) could be applied. In practice this is known to be greatly in error, as repeatedly pointed out (Brett 1964, 1965). Excitement, spontaneous activity, and oxygen-debt replacement (from handling) can elevate the consumption rate over that for the minimum locomotor demand at low velocities by as much as 500%, and usually 300% (Fig. 4, in Brett 1964; p. 82, in Brett 1965). As reported in the present paper (see Fig. 2), it took over 20 hr for the 1965 fingerlings to settle down to steady swimming at 2 L/sec and approach a predicted O_2-consumption rate, and 8 days in the case of the 1969 tests. Higher sustained speeds are subject to similar but proportionately less error from excitement. Speeds which induce fatigue involve an oxygen-debt, of the order of 700 mg O_2/kg at 15 C in fingerling sockeye (Brett 1964), requiring 4–5 hr of postfatigue hyperventilation to repay. Fatigued rainbow trout, from burst swimming, required from 8 to 12 hr to regain normal blood lactate levels (Black 1955; Black et al. 1960).

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[8] The fish averaged 7.9 cm in length (fork or total length not specified) and 4.56 g wet weight. The imposed velocities of 52 and 59 cm/sec equal 6.6 L/sec and 7.5 L/sec. The mean swimming time at these speeds was 19 hr and 6.6 hr, respectively.

At the onset of fatigue at critical swimming speeds salmon struggle to maintain position by repeated bursts causing them to dart forward and drift back before final collapse. These bursts project the fish at two to three times the maximum sustained speed (Bainbridge 1960, 1962). From the power-performance curve computed for sockeye, such bursts, which can be maintained only for 20 sec, can be shown to drive the metabolic demand for oxygen to 10 times the active metabolic rate (Brett 1970, 1972). Finally, very much like any athlete, unless a prolonged training period (over and above most laboratory culture practices) precedes the period of imposed exercise, performance is seriously affected (Brett et al. 1958; Bainbridge 1962).

Unfortunately, Krueger et al. (1968) made no measurements of oxygen consumption, provided no records of performance behavior, and did not give any pertinent history of their experimental animals.

Body composition — Only the mean wet weight (no confidence limits) and weight of lipids for control and postexercise fish are presented by Krueger et al. (1968). The original wet weight of the exercised fish was apparently not taken. For some reason it is assumed that the controls had an identical weight to the unweighed preexercised fish, and that slight differences in lengths were simply chance sampling differences, presumably not statistically different. If no size correction is to be applied, Table 3 of Krueger et al. (1968) can be interpreted to state that coho salmon swimming at 59 cm/sec for 24 hr showed an increase in lipid by 66 mg, and of esters by 48 mg, approximately 25% above the controls.

It is further assumed that the body composition of unexercised and exercised fish was the same. Where gross amounts of body substance are involved, this is an acceptable assumption. However, the loss in protein is estimated at 112 mg, or 2% of the average wet body weight. A small error in assumed gross body composition could result in a large difference in estimated small protein loss. Furthermore, the caloric equivalent is then calculated on the basis of absolute value rather than physiological value (15% error) for comparison with oxygen-consumption deductions.

From the above it is hard to believe that Krueger et al. (1968) have amply demonstrated the presence of large differences in the energetics of coho salmon when strenuously exercised. The evidence for excretion of major unoxidized metabolites from anaerobic metabolism is not convincing.

The application of standard vertebrate oxycalorific equivalents remains tenable when used for fish performance, subject to the same conditions acceptable for any other vigorous vertebrate activity.

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Captan Toxicity to Fathead Minnows (*Pimephales promelas*), Bluegills (*Lepomis macrochirus*), and Brook Trout (*Salvelinus fontinalis*)

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HERMANUTZ, R. O., L. H. MUELLER, AND K. D. KEMPFERT. 1973. Captan toxicity to fathead minnows (*Pimephales promelas*), bluegills (*Lepomis macrochirus*), and brook trout (*Salvelinus fontinalis*). J. Fish. Res. Board Can. 30: 1811–1817.

The toxic effects of captan on survival, growth, and reproduction of fathead minnows (*Pimephales promelas*) and on survival of bluegills (*Lepomis macrochirus*) and brook trout (*Salvelinus fontinalis*) were determined in a flow-through system. In a 45-week exposure of fathead minnows, survival and growth were adversely affected at 39.5 μg/liter. Adverse effects on spawning were suspected but not statistically demonstrated at 39.5 and 16.5 μg/liter. The maximum acceptable toxicant concentration (MATC), based on survival and growth, lies between 39.5 and 16.5 μg/liter. The lethal threshold concentration (LTC) derived from acute exposures was 64 μg/liter, resulting in an application factor (MATC/LTC) between 0.26 and 0.62. LTC values for the bluegill and brook trout were 72 and 29 μg/liter, respectively. The estimated MATC is between 44.6 and 18.7 μg/liter for the bluegill and between 18.0 and 7.5 μg/liter for the brook trout.

The half-life of captan in Lake Superior water with a *p*H of 7.6 is about 7 hr at 12 C and about 1 hr at 25 C. Breakdown products from an initial 550 μg/liter of captan were not lethal to 3-month-old fathead minnows.

HERMANUTZ, R. O., L. H. MUELLER, AND K. D. KEMPFERT. 1973. Captan toxicity to fathead minnows (*Pimephales promelas*), bluegills (*Lepomis macrochirus*), and brook trout (*Salvelinus fontinalis*). J. Fish. Res. Board Can. 30: 1811–1817.

Nous avons mesuré les effets toxiques du captan sur la survie, la croissance et la reproduction du tête-de-boule (*Pimephales promelas*) et sur la survie du crapet arlequin (*Lepomis macrochirus*) et de l'omble de fontaine (*Salvelinus fontinalis*) dans un système à flot continu. Une exposition de 45 semaines à une concentration de 39.5 μg/litre affecte la survie, la croissance et la reproduction du tête-de-boule. Une concentration de 16.5 μg/litre réduit la reproduction. La concentration maximale acceptable du toxique (MATC), basée sur le nombre de fraies et le nombre d'oeufs par femelle, se situe entre 39.5 et 16.5 μg/liter. La concentration de seuil létale (LTC), déterminée par expositions aiguës, est de 64 μg/litre, ce qui donne un indice d'application (MATC/LTC) de 0.26 à 0.62. Les valeurs de LTC pour le crapet arlequin et l'omble de fontaine sont de 72 et 29 μg/litre respectivement. La MATC estimée se situe entre 44.6 et 18.7 μg/litre pour le crapet arlequin et 18.0 et 7.5 μg/litre pour l'omble de fontaine.

La demi-vie du captan dans l'eau du lac Supérieur, d'un *p*H de 7.6, est d'environ 7 h à 12 C et 1 h à 25 C. Les produits de dégradation d'une concentration initiale de 550 μg/litre de captan ne sont pas mortels pour des têtes-de-boule âgés de 3 mois.

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CAPTAN (*cis*-N (trichloromethyl)thio-r-cyclohexene-1,2-dicarboximide)), one of the phthalimide fungicides, is used widely throughout the world. Little information is available, however, concerning the effects of this fungicide on aquatic life. Acute studies by Abedi and McKinley (1967) have demonstrated that 1.0 mg/liter of captan will kill larval zebrafish (*Brachydanio rerio*) in 90 min. Holland et al. (1960) found that 0.32 mg/liter of Captan 50-W (50% captan–50% inert material) killed 50% of exposed rainbow trout (average size 4.8 inches) within 72 hr. A 26-hr LC50 value of 1.30 ppm for *Daphnia magna* was observed by Frear and Boyd (1967). The above experiments were carried out in static water systems. No in-

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formation on flow-through exposures of aquatic organisms to captan could be found in the literature. The purpose of this study was to determine, in a flow-through system, the toxicity of captan to fathead minnows (*Pimephales promelas*), bluegills (*Lepomis macrochirus*), and brook trout (*Salvelinus fontinalis*). Chronic and acute toxicities were determined for fathead minnows, and acute toxicity was determined for bluegills and brook trout. An application factor (Mount and Stephan 1967; Eaton 1970) derived from the fathead minnow chronic and acute data was used to estimate the chronic toxicity values for bluegills and brook trout.

Materials and Methods

CHRONIC EXPOSURE

The design of the chronic exposure study closely followed procedures recommended by the National Water Quality Laboratory Committee on Aquatic Bioassays (Bioassay Committee 1971).

Physical — A proportional diluter and syringe injector (Mount and Brungs 1967) delivered test water and toxicant to the test chambers. A control and five captan concentrations flowed to their respective 30.5- × 30.5- × 61-cm duplicate spawning chambers and 44- × 15- × 18-cm quadruplicate larval chambers. The volumes of water in the spawning and larval chambers were 28.3 and 8.7 liters, respectively. All chambers were separated from one another, and each received a flow of 10.5 tank volumes per 24 hr. The flow rate was selected to maintain the dissolved oxygen above 65% saturation in all chambers.

Before entering the diluter, Lake Superior water was filtered, sterilized with ultraviolet light, and warmed to about 25 C in a stainless steel headbox by a coiled stainless steel heat exchanger. A solenoid valve activated by a thermoregulator relay system (Syrett and Dawson 1972) controlled the flow of hot city water through the heat exchanger. Temperatures in all test chambers were checked daily, and one chamber was monitored continuously with a recording thermometer.

The photoperiod was adjusted the 1st and 15th day of each month, following the normal daylight hours of Evansville, Indiana (represents average U.S. day lentgh). The daylight length at the start of the experiment coincided with the first week of December in Evansville. Because the fish developed more slowly than expected, the peak photoperiod of 15 hr and 15 min was extended and additional 5 weeks to assure them of a 4-month spawning period. Light intensity at the water's surface ranged from 27 to 36 ft-c for the spawning chambers and 33–46 ft-c for the larval chambers.

Chemical — A stock solution containing, by weight, 1.94% technical grade captan (88.4% purity), 0.05% of the surfactant Triton X-100[2], and 98.01% acetone was delivered to the dilution water from a 50-ml glass syringe and Teflon® needle. The outlet of the needle was submersed in the chamber water and attached to an air stone to promote dissolution of the captan. No amounts of acetone or Triton X-100 were added to the control water while the highest amounts were added to the high concentration (63.5 μg/liter), and they never exceeded 14.9 mg/liter and 6.7 μg/liter, respectively. Brungs (personal communication) found that 870 mg liter of acetone in an 80-day exposure and 1.0 mg/liter of Triton X-100 in a 30-day exposure have no deleterious effects on the fathead minnow. In spite of the acetone, Triton X-100, and air agitation, about 12% of the captan (determined by gas-chromatographic analyses) precipitated and collected at the outlet of the Teflon® needle. The precipitate was discarded each day. The original nominal concentrations of captan were increased twice during the experiment. After 3 weeks they were increased by 100% because no difference in survival or growth of the young fish was apparent, and after the 17th week they were increased by 25% because of a measured decrease in all concentrations starting on the 4th week. The captan concentrations between 3 and 45 weeks (termination of experiment) were:

Nominal concn (*μg/liter*)	Measured concentration (*μg/liter*)			
	No. of samples	Mean	Standard deviation	Range
200–250	36	63.5	25.4	16.2–118.2
100–125	63	39.5	12.4	15.9–68.2
50–62.5	63	16.8	4.93	6.9–27.6
25–31.3	63	7.4	2.22	2.9–12.9
12.5–15.6	63	3.3	1.12	1.1–6.8

Captan concentrations were measured once each week for the first 11 weeks and twice each week for the last 34 weeks. Measurements of the high concentration were discontinued between the death of all the first generation fish and the beginning incubation of the control embryos in the high concentration. A duplicate and a spiked sample of control water were analysed with each set of samples. Captan was extracted with 20% methylene chloride/petroleum ether and analyzed by gas chromatography as described by the U.S. Environmental Protection Agency (1971). No interfering chlorinated or organophosphate compounds were found in the control water. Fish food (Oregon Moist) fed to the young and adult fish was examined for pesticide content according to methods described by the U.S. Department of Health, Education, and Welfare (1971). Nothing was found above the detection limits of 10 ng/g for organophosphates and 1.0 ng/g for chlorinated hydrocarbons. Chemical characteristics of the test waters determined each week by methods described by the American Public Health Association (1971) were:

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[2] Mention of commercial products does not constitute endorsement by the U.S. Environmental Protection Agency.

	Mean	Range
Dissolved oxygen	7.2 mg/liter	5.6–8.4
Acidity	3.3 mg/liter	1.8–5.5
Alkalinity	42.0 mg/liter	37–44
Total hardness	45.1 mg/liter	41–49
Temperature	24.9	23.0–26.0
*p*H (median)	7.5	7.1–7.8

Biological — Twenty-five 9-day-old laboratory-cultured fathead minnows were randomly assigned to each of the duplicate spawning chambers (A and B) on September 14, 1971. The fish were photographed as described by McKim and Benoit (1971) after 51 days of exposure to determine extent of growth. On the 51st day, 15 of the surviving fish in each chamber were impartially selected and returned to the spawning chambers. Mature males in excess of five per chamber were removed weekly to reduce territorial competition and were not included in the survival and growth data. All parental fish were sacrificed after 45 weeks of exposure (1 week after cessation of spawning) and were examined to determine sex, gonadal condition, length, and weight.

Groups of 40 1-day-old F_1 fish were reared in the larval chambers for 30 days to determine extent of growth and survival. The young fish were fed Oregon Moist starter three times a day and cultured zooplankton once each day.

Statistical analysis — For statistical evaluation, means of lengths, weights, spawnings/female, eggs spawned/female, and eggs/spawning were transformed to logarithms, and survival data were transformed to arcsin $\sqrt{\%}$ survival. All transformed data were subjected to an analysis of variance ($P=0.05$) and Dunnett's two-tailed comparison of treatment means to control means ($P=0.05$) (Steel and Torrie 1960). A two-way analysis of variance was applied to the growth data of the parental generation to determine if captan affected the growth of one sex more than the other.

ACUTE EXPOSURE

Flow-through — The chronic-test diluter system was also used for acute exposures of 3.5-month-old laboratory-cultured fathead minnows and 1.5-year-old hatchery-reared bluegills and brook trout. In each experiment 10 fish were randomly assigned to each of the duplicate test chambers. Flow rates were 19 tank volumes/24 hr for the fathead minnows and 22 tank volumes for the bluegills and brook trout. Dissolved oxygen, *p*H, alkalinity, acidity, and total hardness of the test water were determined at the beginning, middle, and end of the experiments. Temperatures were recorded daily. Captan determinations were made each day for the first 5 days. A 96-hr TL50 and a lethal threshold concentration as defined by Eaton (1970) were derived by using the method of Litchfield and Wilcoxon (1949).

Static — A static exposure of fathead minnows was used to demonstrate the breakdown of captan and to determine the acute toxicity of the breakdown products. Two groups of 10 3-month-old fathead minnows were exposed to an initial concentration of 550 μg/liter of captan. The test chamber, a 30.5- × 30.5- × 61-cm aquarium divided by a stainless steel screen, contained 30 liters of 23 C Lake Superior water with an initial *p*H of 7.5. Both sections of the chamber were gently aerated throughout the 10-day exposure. The first group was placed in one section immediately after the toxicant was mixed in the water; the second was placed in the other section 3 hr later.

Results

CHRONIC EXPOSURE

All but one of the parental fish died at 63.5 μg/liter of captan in 51 days. Survival in the other concentrations, after 51 days and 45 weeks did not differ significantly from the control (Table 1). At 51 days and 45 weeks of exposure, growth in length was significantly different only at 39.5 μg/liter (Table 1). The lone survivor in 63.5 μg/liter was not considered in the 51-day growth analysis because of a possible bias from one resistant individual. A two-way analysis of variance indicated that the growth of both sexes was equally affected by the toxicant. Mean spawnings/female and mean eggs spawned/female appeared to be adversely affected at 39.5 and 16.8 μg/liter. However, due to variability and especially the absence of spawning in one of the 7.4-μg/liter chambers statistical significant spawning differences could not be shown in any of the concentrations (Table 2).

Embryos from unexposed parents incubated in 63.5 μg/liter did as well as control embryos, but all the larvae died 5–8 days after hatching. One hundred percent mortality occurred within 24 hr when 1-day-old larvae from unexposed parents were placed in this concentration. Growth and survival of the F_1 generation were reduced in 39.5 μg/liter after 30 days (Table 3). No significant difference in growth or survival of the F_1 generation was observed between the control and the three lower concentrations (16.8, 7.4, and 3.3 μg/liter).

ACUTE EXPOSURE

Flow-through — The 96-hr TL50 and lethal threshold concentration (LTC) were determined for the three species based on measured concentrations. The results are listed in Table 4.

Static — The first group of fathead minnows placed in the static concentration of 550 μg/liter immediately after introducing the toxicant died within 8 hr. The second group placed in the same chamber 3 hr later lived without any apparent effects for the 10-day exposure. In a similar study a single group of 10 was exposed to a 500-µg/liter concentration. Six of 10 died within 7 hr when exposed immediately after introducing the captan. All displayed the sympton of feeble swimming at the water surface that Holland et al. (1960) described for rainbow trout. The four that did not die appeared to recover and returned to their normal swimming habits for the duration of the 10-day exposure.

Discussion

Growth and survival of fathead minnows were not adversely affected by chronic exposure to 3.3, 7.4, and 16.8 µg/liter of captan. Postmortem examinations gave no indication that the gonads were immature or abnormal in any of the fish in the 7.4-µg/liter chamber where spawning did not occur. Perhaps the large ratio of males to females (Table 1) resulted in a disruption of normal spawning behavior. Nevertheless, the absence of spawning was not considered to be due to the effects of captan because spawning, although reduced, did occur in the higher concentration chambers. An adverse effect on mean spawnings/female and mean eggs spawned/female is suspected when the results from 39.5 and 16.8 µg/liter are compared to those from the control, 3.3 µg/liter and the 7.4-µg/liter chamber in which spawning did take place.

Statistical evaluation of the data indicates that the maximum acceptable toxicant concentration (MATC), as defined by Mount and Stephan (1967), lies between 39.5 and 16.8 µg/liter, based on survival rate and growth. An application factor (AF) defined by Mount and Stephan (1967) is obtained by dividing the MATC value by the 96-hr TL50. Eaton (1970) suggested that the lethal threshold concentration (LTC) is a better measure of acute toxicity than the 96-hr TL50 and modified the application factor to MATC/LTC. The application factor based on the fathead minnow MATC and LTC lies between 0.26 and 0.62. The estimated MATC (AF × LTC) is between 44.6 and 18.7 µg/liter for bluegills and between 18.0 and 7.5 µg/liter for brook trout.

Abedi and McKinley (1967) observed a dramatic eye and head injury in larval zebrafish exposed to 1.0 ppm of captan. Such injury was not found in 1-day-old fathead minnow larvae killed in the high captan concentration (63.5 µg/liter), nor was it observed in fathead minnow larvae exposed to 1 mg/liter captan. However, this may be due to species differences, because zebrafish larvae exposed to 1 mg/liter of captan in Lake Superior water developed eye damage similar to, but less severe than that reported by Abedi and McKinley (1967).

Captan hydrolyzes in water to tetrahydrophthalimide and tetrahydrophthalic acid; the rate of

TABLE 1. Survival and growth of parental fathead minnows (*Pimephales promelas*) after 51 days and 45 weeks of exposure to various captan concentrations.

	Measured captan concentration (µg/liter)											
	63.5		39.5		16.8		7.4		3.3		0 (control)	
Item	A	B	A	B	A	B	A	B	A	B	A	B
						51 days						
Survival (%)	4	* 0	80	72	84	88	92	84	76	72	88	80
Total length (*mm*)												
Mean	–	–	21.3	* 20.2	21.6	22.0	21.6	22.0	23.4	22.1	23.0	22.4
Range	–	–	28–16	30–13	29–14	32–13	34–13	28–13	33–19	31–14	33–10	30–12
						45 weeks						
Survival (%)	0	* 0	73.3	80.0	100	92.3	100	100	100	90.9	100	90.9
Males/females at termination	–	–	5/6	6/7	6/5	5/7	6/4	5/6	6/5	3/7	5/8	4/6
Mean total length (*mm*)												
Male	–	–	57.4	* 63.7	64.5	67.4	69.2	65.2	61.2	63.3	64.2	69.3
Female	–	–	50.0	* 51.4	50.6	54.9	55.5	57.0	59.2	54.4	58.1	58.5
Mean weight (*g*)												
Male	–	–	2.4	3.2	3.2	3.7	4.0	3.2	2.5	3.1	2.8	3.8
Female	–	–	1.3	1.4	1.3	1.5	1.6	1.7	1.7	1.4	1.7	1.8

*Values are significantly different from control values according to Dunnett's procedure ($P=0.05$).

TABLE 2. Reproductive success and embryo viability in fathead minnows exposed to various captan concentrations.

Item	Measured captan concentration (μg/liter)											
	63.5		39.5		16.8		7.4		3.3		0 (control)	
	A	B	A	B	A	B	A	B	A	B	A	B
Mean spawnings/female	–	–	0.14	0.71	2.4	1.9	0	12.7	10.4	4.6	14.6	9.6
Mean eggs spawned/female	–	–	68	12	485	360	0	1590	1648	400	1533	2173
Mean eggs/spawning	–	–	94.8	83.0	194	202	–	126	159	87	159	148
Hatchability (%)[a]	72.7[b]	66.4[b]	86.0	81.0	91.5	84.8	81.0[c]	87.1	71.6	77.7	76.6	68.1
Number of hatchability samples	3	5	1	2	8	8	8	15	15	12	18	20

[a] Each hatchability sample contained 50 1-day-old embryos.

[b] Control embryos incubated in 63.5 μg/liter.

[c] Embryos incubated in 7.4 μg/liter (A) from 7.4 μg/liter (B).

hydrolysis increases as the *p*H and temperature increase (J. N. Ospenson and D. E. Pack, Chevron Chemical Company, Richmond, Calif., *personal communication*). Captan's half-life in Lake Superior water with a *p*H of 7.6 is about 7 hr at 12 C and about 1 hr at 25 C. The difference between the nominal and measured concentrations in the chronic bioassay was due to the short half-life of captan in the test water. After subtracting the 12% captan that precipitated at the outlet of the needle, the measured concentrations in all test chambers averaged about 30% of the adjusted nominal concentrations. If a constant breakdown rate (a 1-hr half-life) is assumed, calculated test-chamber concentrations would be about 38% of the adjusted nominal concentrations. The difference between the calculated and measured test-chamber concentrations may have been due to small changes in the breakdown rate brought about by small changes in *p*H or temperature. Biodegradation may also have contributed to the breakdown rate especially between the 4th and 17th week when the concentrations failed to reach equilibrium.

Our static bioassays demonstrated that the breakdown of captan is rapid in Lake Superior test water and that the breakdown products from 550 μg/liter captan are not lethal to 3-month-old fathead minnows. Higher levels were not tested. Also, this fish is able to recover from sublethal effects that occur during acute exposures. Toxicity values that are based on initial (nominal) concentrations in static acute exposures are probably much higher than the true toxicity values because of captan's instability in water.

McKee and Wolf (1963) state that only 5% of the waters in the United States that support a good fish fauna have a *p*H less than 6.7. The half-life of captan in Lake Superior water when the *p*H is adjusted to 6.5 is about 8 hr at 23 C and about 40 hr at 12 C. Colder waters will increase its stability,

TABLE 3. Survival and growth of 30-day-old F_1 fathead minnows at various captan concentrations.

	Measured captan concentration (μg/liter)											
	63.5		39.5		16.8		7.4		3.3		0 (control)	
Item	A	B	A	B	A	B	A	B	A	B	A	B
Survival (%)	0[a] *	0[a]	27.5 *	33.8	65.0	61.3	45.0	65.6	47.5	72.5	69.4	72.5
Total length (*mm*)												
Mean	–	–	13.8 *	12.3	14.6	14.9	13.9	16.1	14.2	15.8	15.4	16.9
Range	–	–	25–10	20–7	24–9	24–8	24–7	29–6	27–8	30–7	26–8	28–11
Number of groups[b]	4	4	2[c]	4[d]	4	4	4	4	4	4	4	4

[a] Larvae in 63.5 μg/liter were from unexposed parents.

[b] Each group contained 40 1-day-old larvae.

[c] One group of larvae from control embryos incubated in 39.5-μg/liter concentration.

[d] Two groups of larvae from control embryos incubated in 39.5-μg/liter concentration.

*Values are significantly different from control values according to Dunnett's procedure ($P=0.05$).

TABLE 4. Captan acute toxicity, as measured by 96-hr TL50 and lethal threshold concentration (LTC), for three species of fish in continuous-flow exposures.

Species	Mean temperature (and range) (*C*)	Duration of experiment (*days*)	96-hr TL50 (and 95% CI) (*μg/liter*)	LTC (and 95% CI) (*μg/liter*)
Fathead minnow	25.2 (25.1–25.4)	6	65 (59–72)	64 (58–70)
Bluegill	24.9 (24.8–25.0)	5	72 (47–111)	72 (47–111)
Brook trout	11.8 (11.5–12.0)	8	34 (22–52)	29 (18–46)

but captan will likely break down rapidly in most warm surface waters supporting fish populations to form less toxic or nontoxic compounds.

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Abundance, Survival, and Vertical and Diurnal Distribution of Lobster Larvae in Northumberland Strait, 1962–63, and their Relationships with Commercial Stocks

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SCARRATT, D. J. 1973. Abundance, survival, and vertical and diurnal distribution of lobster larvae in Northumberland Strait, 1962–63, and their relationships with commercial stocks. J. Fish. Res. Board Can. 30: 1819–1824.

Estimates of the abundance of the four planktonic stages of lobster larvae (*Homarus americanus*) taken in a large surface plankton net show that production and survival of larvae in Northumberland Strait in 1962 and 1963 were the lowest on record. Examination of diurnal fluctuations in abundance, and sampling below the surface and at various depths to the bottom, confirm that larvae are concentrated at the surface during daylight hours. The time to next molt of stage IV larvae, captured and retained alive, indicates that settlement takes place about midway through stage IV. Reexamination of earlier results together with these new data now suggests there is some evidence for a relationship between stage IV larval abundance and subsequent commercial lobster stocks, but that sampling errors are too great to permit accurate prediction.

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Des estimés d'abondance de quatre stades planctoniques de larves de homard (*Homarus americanus*) capturés à l'aide d'un grand filet à plancton de surface démontrent que la production et la survie des larves dans le détroit de Northumberland en 1962 et 1963 ont été au plus bas niveau jamais enrégistré. L'examen des fluctuations journalières d'abondance et l'échantillonnage au-dessous de la surface et à diverses profondeurs jusqu'au fond confirment le fait que les larves se concentrent à la surface pendant les heures du jour. Le temps qui s'écoule entre le stade IV et la mue suivante chez des larves maintenues vivantes après capture démontre que la fixation a lieu vers le milieu du stade IV. Un réexamen des résultats antérieurs, ainsi que ces nouvelles données donnent à croire qu'il y aurait une relation entre l'abondance de larves au stade IV et celle des stocks commerciaux subséquents, mais que les erreurs d'échantillonnage sont trop grandes pour permettre des prédictions justes.

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SCARRATT (1964) described the abundance and distribution of lobster larvae (*Homarus americanus*) in the northern part of Northumberland Strait between 1949 and 1961. Both abundance and survival varied from year to year but neither could be related to variations in temperature. It was suggested that the distribution and abundance of stage I larvae reflected the location and size of parent stocks and that surface drift carried larvae to possible areas of settlement. There appeared to be no conclusive relationship between larval abundance and size of subsequent lobster stocks. The present paper presents results of the continuation of this investigation in 1962 and 1963 after which the systematic towing was discontinued. It also reexamines the vertical and diurnal distribution of lobster larvae, and the conclusions of the earlier paper in the light of more recent information.

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Methods

SURFACE SAMPLING METHODS

Half-hour tows were made with a net measuring 12 ft × 3 ft (3.7 m × 0.9 m) in the mouth, floating on 5-gal (23-liter) drums so that the upper edge was approximately 30 cm above the water surface and the net fished a layer approximately 60 cm thick (Wilder 1953; Scarratt 1964). The original 16 meshes per inch silk grit gauze was replaced with a nylon net of approximately 18 meshes/inch (7 meshes/cm). Tows were made at 1 knot. The area fished per tow was therefore 1/1000 naut. mile^2 (3430 m^2). The original 23 sampling stations were reduced to 12 by eliminating alternate stations and three additional stations were established at 5-mile intervals across the center of the area (Fig. 1).

Lobster larvae captured were usually identified and counted at sea.

Diurnal variations in abundance were assessed by means of ½-hr surface tows made at 2-hr intervals throughout six different 24-hr periods. On each occasion eight tows were made during daylight hours and five between sunset and sunrise.

DEEPER SAMPLING METHODS

Subsurface — For a total of 34 ½-hr tows, a second net measuring 12 ft wide × 2 ft deep (3.7 × 0.6 m) was fastened in a frame mounted vertically below the surface net. It sampled the layer between 2 and 4 ft (0.6–1.2 m) below the surface and permitted comparison between the numbers caught in the surface and subsurface layers.

Midwater — Thirteen ½-hr midwater tows were made by weighting the 12-ft × 2-ft net and adjusting the length of tow line to give the desired depth.

Near bottom — This same net (12 ft × 2 ft) was mounted on steel skids 5 ft (1.5 m) long. Ground clearance was about 4 inches (10 cm) and towing was practical only over very smooth bottom. A tickler chain between the skids increased the chance of animals resting on the bottom being captured. Seventeen tows were made, each 15 min long at 1 knot.

Results

ABUNDANCE AND SURVIVAL OF LARVAE IN 1962 AND 1963

The numbers of larvae caught in surface tows in 1962 and 1963 were:

Year	No. of tows	Stage I	II	III	IV	Total
1962	210	4093	343	121	22	4579
1963	238	6519	681	133	43	7376

Weekly catches of each stage were corrected for "time in stage" at prevailing temperatures to give an estimate of larval production (Fig. 2), using the method outlined by Scarratt (1964) and larval stage duration data from Templeman (1936).

Comparison of production of stage I and stage IV estimated in this manner gives a measure for survival over the planktonic larval period (Table 1). Comparison with earlier results (1949–61 mean production per towed area was: stage I — 756.2; II — 111.3; III — 27.4; IV — 8.52, and survival — 1.12%, Scarratt 1964) shows that estimated larval production and survival in 1962 were the lowest on record and that for 5 years beginning 1959, larval survival and the production of stage IV larvae were consistently below average.

DIURNAL VARIATIONS IN ABUNDANCE

Six series of day and night surface tows were completed: 2 in 1962 and 4 in 1965. The results of each are summarized in Fig. 3.

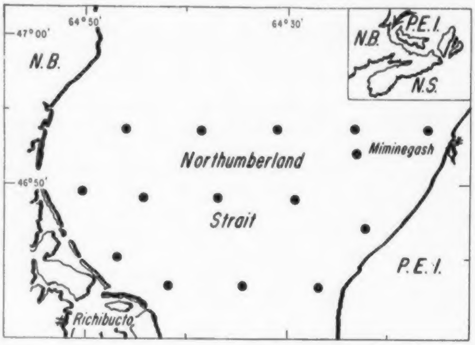

FIG. 1. Northumberland Strait showing larval sample stations 1962–63.

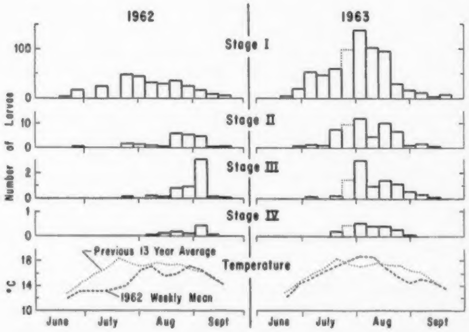

FIG. 2. Estimated weekly production of larval stages I-IV on one towed area; the previous 13-year weekly mean surface temperature and the current weekly means.

TABLE 1. Estimated average production and survival of larvae in one towed area (1/1000 naut. mile²).

Year	Stage I	II	III	IV	% survival I–IV
1962	308.6	23.4	5.0	0.34	0.11
1963	695.9	56.1	8.9	0.93	0.13

Analysis of variance for stage I larvae showed significant variation in the number of larvae between the six samples, which is to be expected, and also between daytime and nighttime tows ($P < .01$). The mean number of larvae taken per tow in daytime (30.5±24.9 SD) was significantly higher than at night (16.8±17.5 SD) ($Z = 2.64$ $P < .01$). The interaction between the two main effects was negligible.

For larvae in stage II, variation between dates was significant ($P < .01$) but there were no significant variations between daytime and nighttime hauls (12.1±16.7 SD vs. 9.2±11.7 SD larvae per tow).

Mean numbers of larvae in stages III (5.8 and 5.9 per tow) and IV (2.6 and 1.8 per tow) were too low for meaningful analysis.

ABUNDANCE AT DIFFERENT LEVELS

Subsurface — Twenty-one ½-hr daytime tows were made with the double nets in July 1962 and the following numbers of larvae caught:

	I	II	III	IV
surface layer	411	8	2	0
subsurface layer	6	1	0	0

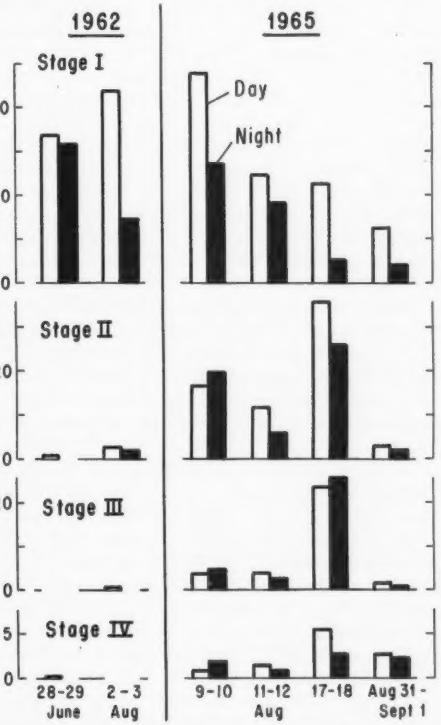

FIG. 3. Mean numbers of larvae taken in daytime and nighttime tows.

In August 1962, a 24-hr series of 13 ½-hr tows at 2-hr intervals made with the double net yielded the following numbers of larvae:

	I	II	III	IV
surface layer	423	32	0	0
subsurface layer	85	3	0	0

The largest numbers of stage I larvae in the lower net occurred around midday and at night, while early morning and evening tows contained fewer in the lower net (Fig. 4). No stage III or IV larvae were taken in either net.

The difference between the seven larvae caught in the lower net in 21 daytime tows in July and the 88 taken in 13 tows in 24 hr in August cannot readily be explained and must be assumed to be random variation. The nets were towed in the same manner by the same crew on all occasions. The weather was comparable, clear with light winds, and surface water temperatures were not appreciably different. No records were made of light intensity so this cannot be excluded as a possible factor.

Abundance in midwater layers — Thirteen ½-hr tows were made on August 22 and 23, 1962, at depths between 4 and 18 m. Totals of eleven stage I and three stage II larvae were taken. As the net was hauled to the surface at the end of the tow with the mouth open, the possibility of larvae in surface

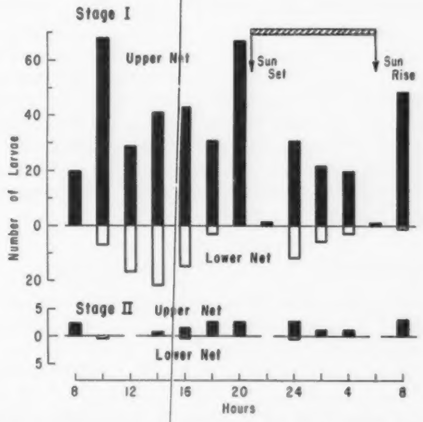

FIG. 4. Abundance of stage I and II larvae in surface and subsurface layers over a 24-hr period.

layers entering the net at hauling cannot be eliminated; however, the numbers taken indicate no general abundance of larvae in the midwater layers. There were no surface net controls taken on either of those dates, but mean number of larvae per tow on the preceding day were: 33.4 stage I, 5.6 stage II, 0.8 stage III, and 0.2 stage IV.

Abundance near bottom — Seventeen 15-min bottom tows were made in depths between 5 and 13 m. No lobster larvae were taken; however, numerous sand shrimps (*Crago septemspinosus*), mysids (mostly *Mysis relicta*), larvae of *Cancer irroratus*, and occasional chaetognaths, amphipods, isopods, copepods, cumaceans, and some postlarval and juvenile fish were captured, indicating the net was sampling effectively.

EFFECT OF WIND VELOCITY ON VOLUME OF WATER FILTERED

The normal method of towing was for the boat to steam slowly in a wide circle with the net about 50 fath (90 m) astern. However, in wind speeds above about 10 knots (18.5 kph) (measured by a Simms anemometer Model RK), the net would "balloon" up out of the water during the upwind part of the tow. This necessitated towing broadside to wind and waves which induced heavy rolling and reduced boat speed. A flow meter fastened in the net mouth for a series of tows measured the effect of wind speed. In winds of less than about 3 knots meter readings varied around 3200 rev per ½-hr tow. Above 4 knots meter readings fell and at 8–10 knots were around 2600 rev, a reduction of 19%. One tow directly into a 10-knot wind gave a meter reading of less than 2000 rev (a reduction of 35%), and a tow directly downwind gave a meter reading of 3400 rev, higher than any of the calm weather tows. Thus, there is considerable variation in water volume filtered due to differences in wind velocity and sea state at different stations or on different days. In the absence of flow meter readings for any except this series of tows, or accurate wind speed measurement for the earlier tows, no meaningful correction can be applied.

ESTIMATES OF THE AGE OF STAGE IV LARVAE

Eleven stage IV larvae captured at the surface in August 1963 were retained alive in individual plastic containers holding 1 liter of sea water, and fed *Artemia salina* nauplii. Two died before molting but the remaining nine were in captivity 13.9±2.5 days before molting to stage V. Numbers of days between capture and molting and the numbers of larvae (in brackets) were as follows: 9 (1); 12 (2); 14 (1); 15 (3); 16 (1); 17 (1). Ambient seawater temperature was about 17 C and prevailing temperature in rearing tanks was about 19 C. From Templeman (1936) duration of stage IV is ca. 20 days at 17 C and ca. 16 days at 19 C. Thus, eight of the nine surviving larvae were between 0 and 5 days in stage IV and one was approximately halfway through the stage at the time of capture.

The absence of old stage IV larvae in the surface waters implies settlement to the bottom taking place before the end of stage IV. Thus, the abundance of stage IV larvae and overall survival is underestimated by reason of the time they were available to the net being shorter than the time in stage IV.

Discussion

SOURCES OF ERROR IN ABUNDANCE ESTIMATES

The original premise that larvae are concentrated at the surface in daylight hours (Templeman and Tibbo 1945) is essentially confirmed except that few larvae were taken at dawn or dusk contrary to what Templeman and Tibbo found in Newfoundland. Few larvae were taken in midwater or bottom water tows indicating no concentrations of larvae other near the surface. There is, however, clear evidence that, on sunny days at least, and also at night, some larvae are located in the layer below that normally fished by the surface net. This might result in an underestimation of abundance of stage I larvae by perhaps 10–15%. The generally lower number of larvae taken at night reinforces the idea that surface daytime tows are probably the most effective method for determining larval abundance and distribution.

Errors due to variations in boat speed with wind velocity are more difficult to assess. There appears to be no effective method of correcting for wind speed in samples taken without flow meter readings, but towing speed and water volume filtered will be lower in high winds and the net should probably not be fished in winds exceeding 10–12 knots.

From observations by Hadley (1908) and personal unpublished observations both in the sea and in the laboratory, and the long average time between capture of stage IV larvae and their next molt, it appears that larvae become strongly negatively phototactic about halfway through stage IV, and the possibility of their being taken by the surface net is reduced. Thus, estimates of larval production using corrections for time in stage IV are probably conservative as the period of any larva available to the net is likely to be shorter than the time between molts. Ghelardi and Shoop (1972) state that settling takes place midway through stage IV, although they do not list their evidence. As the errors in estimating stage IV abundance are probably larger than for earlier stages, overall larval survival is undoubtedly underestimated. In the absence of precise figures for age at leaving the surface it is impossible to say by how much. However, errors will be comparable between years.

RELATIONSHIP OF LARVAE WITH PARENT AND FUTURE COMMERCIAL LOBSTER STOCKS

With the addition of more data, it is now possible to extend the comparisons made by Scarratt (1964) between the abundance of stage I larvae and the commercial stocks at Miminegash, P.E.I. These have been calculated from tag returns during the first 4 weeks of the commercial season by the method of Paloheimo (1963) and give the following numbers of lobsters for the years 1962–69:

Year	Est. stock × 100 (count)
1962	2659
1963	3507
1964	3800
1965	3134
1966	2350
1967	1658
1968	2739
1969	1985

When the numbers of lobsters and larvae are plotted for the years for which there are data (Fig. 5), there is some degree of similarity in their trends. The only years for which there are serious anomalies are 1958–60 when estimated stocks were high and larval productivity was low. However, these 3 years are sufficient to give very low correlation between parent stock and subsequent stage I production ($r = 0.02$). This has already been discussed to some extent by Scarratt (1964). Sutcliffe (1972) believes that freshwater river runoff, by adding to nutrient turnover, may perhaps promote larval survival and growth and finds close positive correlation (personal communication) between stage I larval abundance and discharge from the Miramichi River between 1952 and 1963. Multivariate regression analysis of Miramichi River runoff in June, stage I larvala bundance, and Miminegash stock for the years 1952–63 gives an index of determination $r^2 = 0.718$, implying that stage I abundance is determined partly by parent stock and partly by hydrographic conditions.

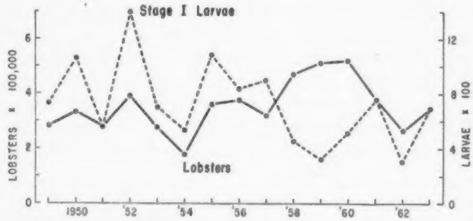

FIG. 5. Relative annual stage I larval production and stock estimates at Miminegash, P.E.I.

Sutcliffe (1972) also shows close correlations between St. Lawrence River discharge and the lobster pack in Quebec 6 years later, and between St. Lawrence discharge and Prince Edward Island lobster landings 5 years later. Flowers and Saila (1972) show multivariate relationships between water temperatures and lobster yields in Maine and Canada with the temperature 6 years previously being the most significant contributor. Seawater temperature and the discharge of major rivers may in some way be related, or may be alternative measures of prevailing conditions. The time lag is approximately equal to the estimated age of entry of lobsters to the fishery, which implies relationships between larval abundance and hydrographic conditions, and between stage IV larval abundance and subsequent stocks.

Scarratt (1964) detected no close correlation between stage IV larval production and commercial lobster stocks at Miminegash 5 or 6 years later when lobsters in this area might be expected to be recruited to the fishery (Wilder 1953). It is reasonable to suppose, however, that a single year-class will enter the fishery over a period of 2 or 3 years, thus smoothing out the effects of individual good or poor years for larval production. When the 3-year running means of stage IV larval production and estimated legal stock at Miminegash 6 years later are compared, a correlation coefficient, $r = 0.64$, is obtained which with 12 df gives $0.02 > P > .01$ (Note: earlier data are taken from Scarratt 1964) Thus, in spite of the errors in estimating larval abundance, 36% of the variability of subsequent commercial lobster stocks is dependent upon stage IV larval production which is therefore inadequate for predictive purposes. Nevertheless, the period of low stocks and poor landings in the mid 1960s can be attributed in part to the years of below average larval production beginning in 1958.

Acknowledgments

I am indebted to Messrs D. E. Graham and I. Rote and to the crew of *MB Pandalus II* for assistance in the field; to Dr D. G. Wilder for permission to use data from the Miminegash fishery, and to Dr Wilder and Mr S. Messieh for their criticism of the manuscript.

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Growth Rates and Nitrogen and Carbohydrate Contents of Juvenile Clams, *Saxidomus giganteus*, Fed Three Species of Algae

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WALNE, P. R. 1973. Growth rates and nitrogen and carbohydrate contents of juvenile clams, *Saxidomus giganteus*, fed three species of algae. J. Fish. Res. Board Can. 30: 1825–1830.

Estimates were made of the increase in live and dry weights and in the content of ash, organic matter, carbohydrate (as glucose), and nitrogen when juveniles of the clam *Saxidomus giganteus* were fed for 21 days at various concentrations of *Tetraselmis chui*, *Isochrysis galbana*, and *Phaeodactylum tricornutum*. The condition index (organic weight as a percent of total dry weight) increased in all the experimental conditions with a mixture of *I. galbana* and *T. chui*, yielding a significantly higher index than either species on its own. The relative gain in glucose was greater than the increase in live weight or in nitrogen. The increase in live weight was such that the nigrogen content was approximately constant at 6–7 μgN/mg live weight irrespective of the feeding conditions. The N:glucose ratio decreased with increasing concentrations of *I. galbana* and *P. tricornutum*, and at the higher concentrations, where the maximum growth rate of clams occurred, the ratios were lower than in any of the clams fed on *T. chui*.

WALNE, P. R. 1973. Growth rates and nitrogen and carbohydrate contents of juvenile clams, *Saxidomus giganteus*, fed three species of algae. J. Fish. Res. Board Can. 30: 1825–1830.

Après avoir soumis des coques (*Saxidomus giganteus*) pendant 21 jours à des régimes contenant divers niveaux de *Tetraselmis chui*, *Isochrysis galbana* et *Phaeodactylum tricornutum*, nous avons calculé l'augmentation de poids vif et sec et celle du contenu en cendres, matière organique, hydrocarbures (sous forme de glucose) et azote.

L'indice d'embonpoint (poids de la matière organique exprimé en pourcentage du poids sec total) augmente dans toutes les conditions expérimentales avec un mélange *I. galbana*–*T. chui*, donnant un indice nettement plus élevé que lorsque l'une ou l'autre espèce est utilisée seule. Le gain relatif en glucose est plus grand que l'augmentation de poids vif ou d'azote. L'augmentation de poids vif est telle que la teneur en azote demeure à peu près constante à 6–7 μg N/mg de poids vif, quelles que soient les conditions d'alimentation. Le rapport N: glucose diminue avec une augmentation de concentration d'*I. galbana* et de *P. tricornutum* et, aux concentrations élevées auxquelles se produit la croissance maximale des coques, les rapports sont plus bas que chez toutes les autres coques nourries de *T. chui*.

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THIS paper reports the growth and the relative changes which occurred in the nitrogen and carbohydrate content of the meat of juveniles of the clam *Saxidomus giganteus* when fed on several concentrations of three species of algae (*Isochrysis galbana* (Parke), *Tetraselmis chui* (E. G. Prings. ex Butch.), *Phaeodactylum tricornutum* (Bohlin)), and on an *I. galbana–T. chui* mixture. Previous studies have demonstrated that different species of algae support different rates of shell growth or whole live weight of larval and juvenile bivalves (Walne 1970a; Davis and Guillard 1958). Less frequently food value has been estimated by considering the proportion of larvae which successfully complete metamorphosis (Helm 1969). Experiments of this type for spat usually last only for 2–4 weeks and it is possible that the reliance on shell growth as a measure of the growth response of the animal has overlooked changes which may occur in the organic matter. The two 21-day experiments reported in this paper, using three size groups of clams, suggest that diets of different species of algae can cause changes in body composition. These experiments were made at the Pacific Biological Station, Nanaimo, B.C., in 1972.

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Method

Juvenile clams were cultured in a recirculation system similar to that used for oysters (Walne and Spencer 1973) and quahogs (Walne and Dean 1967). Rectangular wooden tanks (30 × 60.5 × 35 cm deep), painted internally with an epoxy resin, were used as the experimental vessels; each held 50 liters of filtered sea water. The animals were contained in Perspex trays with a base size of 9 × 15 cm, hung at the surface of each tank so that about 5 cm of water covered the base. Since the edge of the trays was above the water surface, water sprayed onto the surface had to pass downwards past the animals and through the base, which was made from a nylon net with a mesh size of 526 μm. A small plastic centrifugal pump bolted to the side of the tank pumped water from near the bottom and delivered it through a perforated PVC distribution pipe suspended above the water surface. Sixteen 2.4-mm holes were drilled in the distribution pipe so that four sprays of water entered the top of each tray to give a flow of 0.8 liter/minute per tray.

The sea water used came from the laboratory supply, for which the intake main was situated at a depth of 18.3 m. Warmed water as well as water at ambient temperature was supplied, and these were blended to give water at 18 C. Although the natural phytoplankton in the water were sparse, they were reduced by filtering, first through a coarse filter and then by a fine filter, to remove particles down to 1 μm. Throughout the two experiments the salinity was in the range 27.5–29.5‰. The 12 tanks used stood together in two blocks in a culture room and the animals in each tank were moved to a new position at each water change. The sea water was changed twice a week, at which time the spat were washed free from detritus and the tanks, pumps, and trays were cleansed.

The three species of algae were cultured in hard-glass carboys holding 12 or 18 liters of medium. The carboys were aerated and illuminated continuously but, because CO_2 was not added, growth tended to be slow and the *p*H high — about 9.0. The culture medium was filtered sea water enriched with nutrients similar to those used at Conwy (Walne 1966) except that $NaNO_3$ and $NaH_2\text{-}PO_4 \cdot 2H_2O$ were used at 75 and 25% strength, respectively.

The simple culture conditions used gave a relatively slow growth rate, and the high *p*H (ca. 9.0) of the medium indicated that the supply of CO_2 was inadequate for rapid photosynthesis and cell division. The cells of *I. galbana* had a volume of 28–34 μm^3, which was about half that usually obtained at Conwy (57 μm^3), while the dry cell weight (26 $\mu g/10^6$ cells) was higher. Both *T. chui* and *P. tricornutum* also appeared to have a smaller cell, although the weight of *T. chui* (about 0.2 mg/10^6 cells) was similar to that of *T. suecica* (Walne and Spencer 1973).

Experiment B was made immediately after experiment A, and the cultures of *T. chui* used for food were the same as those used in experiment A, but different and younger cultures of *I. galbana* and *P. tricornutum* were used. During experiment B, *T. chui* was fed on nine occasions and on six of these the same culture was used.

When required for feeding, the cell concentrations and median cell volumes (Table 1) were estimated using a model B Coulter counter calibrated with polyvinyltoluene latex particles of 3.49 μm diameter. Duplicate estimations of the dry weight of algal material were made on three occasions in each experiment by filtering 25–100-ml samples through GF/C glass-fibre paper, washing briefly with distilled water and drying at 100 C. From these data the mean dry weights of 10^6 cells were calculated. These dried samples were also used for estimation of N content.

The clam spat used were obtained from cultures originating from several cross fertilizations made with stripped gametes. The larvae had been reared on a mixture of *Monochrysis lutherii* Droop and *I. galbana*, and after metamorphosis the food was changed to *M. lutherii* and *P. tricornutum*. From their appearance the spat had grown slowly, but no sign of any recent substantial mortality was seen. Chemical analyses (Table 2) showed that they were in poor condition compared with their condition at the end of their feeding trials.

At the beginning of each experiment the spat were 16–17 weeks old. Before use the spat were selectively graded through sieves to reduce the size range. In experiment A the largest spat (batch 1) were those retained

TABLE 1. The algal cultures used in experiments A and B. The median cell volume was estimated each time the clams were fed, and the dry weight three times in each experiment. The last column is the dry weight of algae added per liter to those tanks fed 2.5 cells *Tetraselmis chui*/μliter or the equivalent volume of other species.

Experiment	Species	Median cell volume (μm^3 ± SE)	% N	Dry weight 10^6 cells (μg ± SE)	Per liter (mg)
A	*Isochrysis galbana*	23.3±1.9	5.8±0.8	25.7± 3.8	0.688
	Tetraselmis chui	301.1±6.6	5.7±0.3	234.3± 7.3	0.586
B	*I. galbana*	33.7±1.1	5.4±0.7	25.0±0.6	0.592
	T. chui	316.1±8.9	6.3±0.1	214.3±26.0	0.536
	Phaeodactylum tricornutum	32.6±1.1	5.1±0.6	17.0± 1.5	0.418

between 1.5-and 1.8-mm meshes, while batch 2 were those retained between 1.3-and 1.5-mm meshes. In experiment B the spat were retained between 1.8-and 3.0-mm. The spat were divided at random between the experimental treatments by successively adding 25 to each tray until the required total was reached. Two hundred and fifty spat were placed in each tray in experiment A and 100 spat in each tray in experiment B.

After each water change sufficient algal culture was added to give the required concentration of food. The grazing activity of the clams was sufficient for the food level to be gradually reduced until the next water change.

TABLE 2. Sizes and compositions of three batches of *Saxidomus giganteus* initially and after 20 or 22 days feeding on three species of algae singly and in a mixture.

	Food and level		Weight (*mg*)				µg/mg live wt		Glucose/Nitrogen ratio
			Live	Dry	Ash	Organic	Glucose	Nitrogen	
			Experiment A						
Batch 1	Initial size		3.64	1.86	1.68	0.18	3.4	5.6	0.62
	T. chui	2.5/µliters	4.55	2.61	2.27	0.34	12.9	6.0	2.14
		5.0 "	5.25	2.84	2.51	0.34	12.3	6.7	1.84
		7.5 "	5.51	2.81	2.47	0.33	11.3	5.9	1.90
		10.0 "	5.34	2.85	2.43	0.40	12.8	7.3	1.76
	Mixture	1	4.89	2.66	2.26	0.40	12.9	6.8	1.90
		2	5.25	2.96	2.51	0.45	17.5	7.0	2.49
		3	7.90	3.93	3.36	0.57	12.3	6.7	1.82
		4	7.45	4.37	3.81	0.56	12.4	7.6	1.62
	I. galbana	1	5.20	2.78	2.40	0.38	13.4	6.1	2.18
		2	8.11	4.11	3.57	0.53	9.5	7.4	0.98
		3	8.71	4.27	3.64	0.63	7.2	7.9	0.91
		4	9.37	4.41	3.78	0.64	6.7	7.2	0.92
Batch 2	Initial size		2.43	1.22	1.08	0.14	3.4	5.7	0.60
	T. chui	2.5/µliters	2.61	1.63	1.44	0.20	13.3	7.0	1.91
		5.0 "	3.15	1.83	1.61	0.22	13.7	6.8	2.00
		7.5 "	3.36	1.99	1.73	0.26	13.9	7.4	1.88
		10.0 "	3.34	1.96	1.71	0.24	14.1	7.7	1.84
	Mixture	1	2.99	1.83	1.57	0.26	14.6	7.8	1.87
		2	3.33	1.97	1.72	0.25	17.0	9.0	1.89
		3	5.31	2.90	2.47	0.42	12.8	6.6	1.94
		4	5.18	2.70	2.30	0.40	12.3	7.6	1.62
	I. galbana	1	3.52	1.92	1.65	0.27	12.0	6.8	1.76
		2	5.29	2.88	2.49	0.39	7.1	7.7	0.92
		3	6.14	3.01	2.59	0.42	6.6	7.4	0.88
		4	5.81	2.94	2.53	0.41	7.1	8.2	0.86
			Experiment B						
	Initial size		8.80	4.74	4.18	0.57	6.4	6.6	0.97
	T. chui	2.5/µliters	11.53	6.24	5.46	0.78	13.4	6.4	2.10
		5.0 "	11.48	6.42	5.61	0.81	15.8	6.7	2.37
		7.5 "	10.70	6.15	5.40	0.76	17.0	6.8	2.51
	I. galbana	1	11.40	6.20	5.40	0.81	16.6	6.7	2.47
		2	19.49	10.76	9.36	1.40	12.7	6.5	1.95
		3	22.37	11.77	10.24	1.53	11.5	7.4	1.56
	P. tricornutum	1	10.87	5.94	5.15	0.78	14.6	7.1	2.04
		2	11.65	6.50	5.67	0.83	15.9	7.2	2.20
		3	14.48	8.20	7.24	0.95	10.7	6.6	1.62

A range of food levels was used for each food species in the expectation (Walne 1970a) that the higher levels would provide a diet on which the clams would grow at their fastest rate appropriate to the algal species. In both experiments the initial concentration of all three species of algae was based on a diet of *T. chui* (experiment A 2.5, 5.0, 7.5, and 10.0 cellsμ/liter; the highest concentration was omitted in experiment B). In both experiments the other species were added in such quantity that the total volume of algal cells was equivalent to the corresponding volume of *T. chui*. Experiment A also included a mixture of equal volumes of *T. chui* and *I. galbana*. As well as adding algal culture at each water change a half ration was fed on the 2nd day of the last 4-day period between changes in experiment A. In experiment B a full ration was fed on the 2nd day after each water change.

The sizes of the spat were estimated in representative duplicate samples of 250 spat in experiment A and 100 spat in experiment B at the beginning of each experiment and for all the spat at the end of the experiments. The live weight was obtained by washing the spat into a small tared sieve and weighing after the removal of surplus water through the mesh base with a dry tissue. The spat were then counted, transferred to a dry stoppered bottle, and stored in a deep freeze for subsequent chemical analyses. When these analyses were made the spat were thawed, transferred to a tared weighing bottle, and weighed. The spat were then thoroughly crushed in the bottle with a plastic rod until the sample was reduced to a thick soup. Two subsamples (100–150 mg) for carbohydrate analysis were withdrawn with a spatula and washed into a small hand-held tissue grinder. The weights of these samples were obtained by difference from repeated weighing of the weighing bottle. Four further samples were then withdrawn, placed on tared trays of aluminum foil, weighed, and dried overnight at 100 C. After drying two were used for determination of ash weight and two for estimation of nitrogen content.

Carbohydrate (as glucose) was estimated by the anthrone method (Hewitt 1958; Strickland and Parsons 1960). The samples were thoroughly ground, transferred to a graduated centrifuge tube, made up to 10 ml with distilled water and well agitated. Duplicate 0.5-ml subsamples were incubated in a boiling water bath for 7 min with 5 ml of freshly prepared anthrone reagent. The intensity of the green-blue color was read at 620 mμ in a 1-cm cell on a Beckman DU-2 spectrophotometer within 1 hr of preparation. A glucose standard containing 100 μg/ml was incubated at the same time with each set of samples. Trials showed that the color was stable for at least 1 hr in cooled samples and the absorption curve was similar to that given by glucose. Presumably the carbohydrate reserve is mainly in the form of glycogen and the results are given as total carbohydrate, expressed as glucose equivalents.

The nitrogen samples were estimated in a Coleman nitrogen analyzer, using "Cuprox" in the combustion tube and "Cuprin," "Cuprox," and silver vanadate in the postcombustion tube. In this paper the data are reported as nitrogen. Most of the nitrogen will have come from the protein constituents of the tissues and shell, and an estimate of the protein content can be obtained by multiplying the nitrogen values by 6.25.

The ash samples were prepared by heating in a muffle furnace at 450–500 C for at least 6 hr. Since both the ash and nitrogen samples were weighed before and after drying, the data from the four samples were pooled for the estimate of dry weight. The difference between dry weight and ash weight gives an estimate of the organic matter content but as this is only about 15% of the dry weight, and it includes the accumulated experimental errors of the various weighings, the accuracy of the estimate is not as high as that of those factors which were measured directly.

Results

The clams grew well and at least doubled their live weight when fed on *I. galbana*. Maximum growth was obtained when the algal volume offered was equivalent to an enrichment of 7.5 cells *T. chui* per μliter (level 3) in experiment A. This corresponded on average to about 2300 $\mu m^3/\mu$liter of algal material or, on a dry weight basis, about 1.7 mg/liter of *T. chui*, 1.9 mg/liter of *I. galbana*, and 1.2 mg/liter of *P. tricornutum*.

The level of 7.5 cells *T. chui*/μliter corresponds to 1–2 mg/liter of dry organic material. As the dried alga contained 4–7% N (Table 1), the particulate N at the most favorable level was 40–140 μg/liter. Carbon (not analyzed) was probably 45–50% of the dry weight of the algae on an ash-free basis (Strickland 1965), giving 0.5–1.0 mg C/liter at the most favorable feeding level.

The low proportion of carbohydrate in the clams at the beginning of the trials compared with the levels attained after feeding suggests that the spat were in poor condition. This is supported by the changes which occurred in the condition index ($\frac{\text{mean dry ash free weight}}{\text{mean dry weight of spat}} \times 100$). This showed a significant increase in all the diets tested:

Food	Mean ± SE
Initial	11.13±0.58
T. chui	12.67±0.21
T. chui/*I. galbana*	14.21±0.34
P. tricornutum	13.60±0.50
I. galbana	13.68±0.19

In experiment B there was little difference in the final mean sizes of the clams grown in the three concentrations of *T. chui*.

As the grazing activity of the clams had an appreciable effect on the algal density, the average cell density on which the animals fed was less than the concentration provided at the time of the water change. In experiment A the remaining food was estimated in the tanks with *I. galbana* on 3 days and 4 days after feeding, and the percentage of food left in suspension on each occasion was:

Level	1	2	3	4
3 days after	54.5	38.6	43.9	52.2
4 days after	n.r.	7.8	22.0	36.0

A similar series of counts in experiment B 2 days after feeding showed that less than 50% of the food was left, the percentages being:

Level	*T. chui*		*I. galbana*		*P. tricornutum*	
1	40.8	40.4	31.2	32.0	23.8	25.4
2	39.6	22.0	26.5	24.0	39.0	41.0
3	46.9	33.0	25.4	28.8	35.7	30.9

The estimations of glucose showed that this increased at a greater rate than the live weight in all the trials (Table 3). For example, in experiment A the fastest growth led to a live weight increase of two or three times, while the glucose equivalent per animal increased by a factor of 5–8. The mixed diets supported the greatest rate of increase. In experiment B, where the animals were initially larger and in better condition, the rate of growth was not so great but as in experiment A the relative gain in glucose equivalent was greater than the gain in live weight. The estimated glucose equivalent on a unit live weight basis (µg glucose/mg live weight) shows that in experiment A this was approximately constant at 12–14 µg/mg in the clams fed on either *T. chui* or the mixed diet, but when fed on *I. galbana* it decreased from about 13 to 6 µg/mg with increasing concentration of food. Experiment B shows a similar pattern of a reduced proportion of glucose in those clams which had grown most rapidly.

The rate of increase in nitrogen (Table 3) in clams fed on any of the diets was not as marked as the rate shown by the carbohydrate content. Expressed as µg per mg live weight it was a little higher at the end of both experiments than initially, and apparently levelled out at approximately 6–7 µg/mg live weight in all the feeding regimes tested.

The differences in the rates of accumulation of nitrogen and glucose by the spat led to changes in the N:glucose ratio (Table 2). This ratio was 1.0:0.6 and 1.0:1.0. initially in experiments A and B, respectively. A diet of *T. chui* led to an approximately constant ratio of 1:1.9 in experiment A and 1:2.3 in experiment B. In the mixed diet in experiment A the ratio was similar to that obtained with *T. chui*, except for a possible decrease at the highest level. A different pattern emerged in the clams fed on *I. galbana* in both experiments. At the lowest level of food the ratio was comparatively high and comparable to that obtained with *T. chui*, but as the abundance of food increased the ratio declined in both experiments to a level below that obtained with any concentration of *T. chui*. Only three levels of *P. tricornutum* were tested, but the results suggest that the pattern was similar to that found for *I. galbana*.

Discussion

The present study suggests that differences in the food supply can alter the protein:carbohydrate ratio in the flesh of clams. The ratio is affected by the species of algae, by the level at which a given species is fed and possibly by the physiological state of an algal species. In the three trials using *I. galbana* and the one trial with *P. tricornutum* the ratio was lower at the higher food levels than the ratio on a sparse diet. A low level of a good diet — *I. galbana* — produced the same accumulation of carbohydrate and high N:glucose ratio as did all levels of the relatively poor diet. The rates of accumulation of nitrogen and carbohydrate shown by the spat fed on the mixed diet in experiment A are illuminating. The accumulation of nitrogen in those clams fed at levels 2, 3, and 4 of the mixture

TABLE 3. Factors by which live weights and glucose and nitrogen contents of the clams increased in the two experiments (two batches in first).

Food and level		Live weight 1	Live weight 2	Glucose 1	Glucose 2	Nitrogen 1	Nitrogen 2
Experiment A							
T. chui	1	1.2	1.1	4.7	4.2	1.4	1.3
	2	1.4	1.3	5.2	5.2	1.7	1.6
	3	1.5	1.4	5.0	5.6	1.6	1.8
	4	1.5	1.4	5.5	5.7	1.9	1.8
Mixture	1	1.3	1.2	5.0	5.2	1.6	1.7
	2	1.4	1.4	7.3	6.8	1.8	2.2
	3	2.2	2.2	7.8	8.2	2.6	2.5
	4	2.0	2.1	7.4	7.7	2.8	2.8
I. galbana	1	1.4	1.4	5.6	5.1	1.6	1.7
	2	2.2	2.2	4.7	4.5	3.0	2.9
	3	2.4	2.5	5.0	4.8	3.4	3.3
	4	2.6	2.4	5.0	4.9	3.3	3.4
Experiment B							
T. chui	1	1.3		2.7		1.3	
	2	1.3		3.2		1.3	
	3	1.2		3.2		1.2	
I. galbana	1	1.3		3.4		1.3	
	2	2.2		4.4		2.2	
	3	2.5		4.6		2.8	
P. tricornutum	1	1.2		2.8		1.3	
	2	1.3		3.3		1.4	
	3	1.6		2.8		1.6	

was intermediate in rate between those fed at levels 1 and 2 on *I. galbana* (Table 3). However, the accumulation of carbohydrate by those spat which were fed on the mixture, where they had access to *T. chui*, was considerably more than those which were fed solely *I. galbana*.

Growth was probably regulated closely by the assimilation of nitrogen, i.e. protein, while considerable variation in the accumulation of carbohydrate could be accepted. On a unit weight basis the N content increased slightly in the first experiment from about 5.6 μg/mg live weight to 7.2; in the second experiment it remained approximately constant at 6.6 μg/mg. In both experiments carbohydrate accumulated to a greater extent in those animals which grew less well, whereas those fed on the best diet, *I. galbana*, tended to accumulate less carbohydrate. Taking all trials together the glucose content, expressed as a percentage of the dry organic weight, was 19.37 ± 1.43% (95% confidence interval) in clams fed *T. chui* and 13.81 ± 3.22% in clams fed *I. galbana*.

There is considerable variation in the protein: glycogen ratio in wild populations of various species of oysters (Walne 1970b), and Bayne and Thompson (1970) report trends in this ratio in wild populations of *Mytilus* as well as those exposed in the laboratory to temperature and food stresses. Gabbott and Walker (1971) found no change in the protein: glycogen ratio in field or experimental populations of *Ostrea edulis*, despite a considerable temperature and food stress being applied, and they suggest that the ratio is not a good indicator of stress.

Large differences have been observed in the food value of various species of algae to grazing marine animals but generally the reasons for these differences are unknown (Walne 1970b; Cowey and Corner 1966). In this study the explanation probably lies in the protein fraction, since large amounts of glucose were accumulated even on a poor diet or at low concentrations of good food. Studies on amino-acid composition of algae relative to the filter-feeders do not suggest that an explanation can be provided in these terms. At present it seems likely that the differences in food value depend on the relative assimilation of N from different algal proteins, analogous to the situation which occurs in land animals (Maynard and Loosli 1969). The proteins will differ between species, and the results obtained with *T. chui* suggest that they may vary within a species when the culture conditions are altered.

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First Records, Description, Distribution, and Notes on the Biology of *Bathyraja richardsoni* (Garrick) from the Northwest Atlantic

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TEMPLEMAN, W. 1973. First records, description, distribution, and notes on the biology of *Bathyraja richardsoni* (Garrick) from the northwest Atlantic. J. Fish. Res. Board Can. 30: 1831–1840.

Eighteen *Bathyraja richardsoni* (Garrick 1961), 95–174 cm in total length were taken by bottom longline from southern Labrador to Georges Bank, 17 at 1810–2360 m, and one at 1370–1500 m. These are the first records for the western Atlantic. Studies of morphometrics, of numbers, of form, and arrangement of spines, dermal denticles, and teeth, and of body color in these skates amplify the description of the species, known previously only from New Zealand (the holotype) and the northeast Atlantic (eight specimens). There is, however, appreciable variation in the distribution and abundance of dermal denticles between the new specimens and the holotype. These specimens also have middorsal caudal spines instead of the middorsal caudal row of fleshy oval structures (some with a central tubercle of enamel) of the holotype, which are related in this paper to scar areas from lost spines.

Some information is provided on weight–length, liver weight, and fatness, vitamin A of liver oil, and length at sexual maturity. Food was mainly fish.

The trematode *Otodistomum veliporum* occurred in 5 of 16 stomachs and the cestode *Onchobothrium pseudouncinatum* in 6 of 16 intestines. A copepod, tentatively identified as *Lernaeopodina longimana*, was found on the gills of one of five specimens.

TEMPLEMAN, W. 1973. First records, description, distribution, and notes on the biology of *Bathyraja richardsoni* (Garrick) from the northwest Atlantic. J. Fish. Res. Board Can. 30: 1831–1840.

Dix-huit *Bathyraja richardsoni* (Garrick 1961), mesurant 95–174 cm de longueur totale, ont été capturés sur des palangres de fond entre le Labrador méridional et le banc Georges, 17 à 1810–2360 m et un à 1370–1500 m. Il s'agit de premières mentions pour l'Atlantique occidental. Des études de morphométrie, du nombre, de la forme et de l'agencement des épines, des denticules dermaux et des dents, et de la coloration du corps amplifient considérablement la description de l'espèce, connue auparavant seulement de la Nouvelle-Zélande (l'holotype) et du nord-est de l'Atlantique (huit spécimens). Il y a toutefois des variations appréciables dans la distribution et l'abondance des denticules dermaux entre ces nouveaux spécimens et l'holotype. Ces spécimens ont également des épines caudales mi-dorsales au lieu de la rangée caudale mi-dorsale de structures charnues ovales (quelques-unes avec un tubercule d'émail central) observées chez l'holotype, et qui, dans le présent travail, sont considérées comme marquant l'emplacement de cicatrices résultant de la perte d'épines.

Nous présentons quelques données sur la relation poids-longueur, le poids de foie, l'état d'embonpoint, le contenu en vitamine A du foie et la longueur à la maturité sexuelle. La nourriture est constituée surtout de poissons.

Nous avons trouvé le trématode *Otodistomum veliporum* dans 5 sur 16 estomacs et le cestode *Onchobothrium pseudouncinatum* dans 6 sur 16 intestins. Un copépode, identifié d'une manière tentative comme étant *Lernaeopodina longimana*, a été trouvé sur les branchies de un sur cinq individus.

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I have obtained 18 *Bathyraja richardsoni* (Garrick 1961) off eastern Canada and the United States, the first records from the western Atlantic. In this paper I describe their distribution, morphometric characteristics, number and form of spines, dermal denticles, and teeth, and color, weight, sexual maturity, food, parasites, and relationships to the holotype and to eight specimens known from the northeast Atlantic. The description of a large number of specimens adds considerably to earlier descriptions of this species.

Bathyraja richardsoni was described by Garrick (1961) as *Raja richardsoni* from a large female specimen taken on longline at 2400 m in Cook Strait, New Zealand in 1956. Professor Garrick (personal communication June 1970) says that no additional specimens have been taken off New Zealand. Templeman (1973) has shown that this skate is a species of *Bathyraja* as described by Ishiyama and Hubbs (1968), Stehmann (1970), and (as *Breviraja*) Ishiyama (1958), and the name is now *Bathyraja richardsoni* (Garrick 1961).

Forster (1965, 1967, 1968) reported the capture of eight *B. richardsoni* taken on longline in deep water of the northeast Atlantic in 1964–67. These consisted of five males 1133–1262 mm in total length and three females 1192–1455 mm TL (personal communication).

Materials and Methods

Bathyraja richardsoni were caught in the northwest Atlantic in deep water explorations by the research vessel *A. T. Cameron* using bottom longline. The bait was squid; no. 6/0 Pflueger cod hooks and smaller numbers of larger no. 12 halibut hooks were used. The skates were relatively more plentiful on the cod hooks.

The longline was usually out from 8–11 hr from the completion of setting to the beginning of hauling, but a considerable part of this time was probably taken for settling to bottom. The fish appeared to be taken on or near bottom.

The fish were measured and usually weighed shortly after capture, frozen on board ship, thawed in crushed ice, weighed, and examined in the fresh condition on shore 11–32 days after capture. The spring balances used on the ship were checked immediately before and after each cruise and those used on shore were also checked and the necessary small adjustments made to the weights. The holotype of Garrick (1961) and the Plymouth specimens of Forster (1965) were measured by these authors after preservation in formalin (the holotype in 10% formalin, personal communication Garrick).

Most body proportion measurements were taken as in Bigelow and Schroeder (1953, p. 3–4) as shortest distances between parallel perpendicular planes. The others (items 11–13, 17, 23–25, 31–37, Table 2) were taken between points. Garrick (1961) and Forster (1965) also followed Bigelow and Schroeder (personal communications).

Total length and all other measurements which could be taken dorsally were obtained with the fish resting on its ventral surface. Measurements 7–10 of Table 2, related to the cloaca, were naturally taken with the fish resting on its dorsal surface. Although these measurements were taken as the shortest distances between perpendicular planes, the totals of snout to midcloaca and of midcloaca to tip of tail, taken ventral surface upward, were usually slightly greater than the total length of the fish measured with ventral surface downward. These measurements (7 and 8, Table 2) were adjusted proportionately so that the total equalled the total length of the fish. Item 9 (posterior border of cloaca to tip of tail) was adjusted accordingly. Because the holotype lacked the tip of the tail but had a normal first dorsal, and because there was marked variation in the relative length of the tail posterior to the dorsal fins, I used the distance from snout to anterior origin of the first dorsal, instead of the more usual total length, as the base with which other measurements are compared.

I have not used greatest width of disc as a base for other body proportions as proposed by Hubbs and Ishiyama (1968) because repeated measurements of skates in the fresh condition showed that this measurement is highly variable. I measured the greatest width of the disc with the skate in its apparently normal shape, and not the greatest possible width obtained by pulling the pectorals abnormally forward.

As Forster's (1965) measurements of his two specimens from snout to midcloaca and from midcloaca to tip of tail totalled 101.4 and 102.6% of the total length, I multiplied them by 0.9862 and 0.9747 to bring their totals to 100% of the total length before using them in Table 2.

Also, because for Garrick's (1961) holotype the partial posterior measurement from mid-cloaca to tip of tail was not available because of the injured tail, the distance from snout to midcloaca was reduced by the average of the factors for Forster's two specimens (0.9805) before being used in Table 2.

In Table 2, the basic distance, from snout to anterior origin of first dorsal, was obtained for all specimens by adding the adjusted length from snout to midcloaca to the actual length from midcloaca to origin of first dorsal.

The count of median dorsal spines on the tail region included the scars of lost spines. When the scars were so indistinct that a reasonably accurate count could not be made, the dorsal spine number was not recorded.

Distribution

Bathyraja richardsoni were taken from off southern Labrador to off Georges Bank (Fig. 1, Table 1). Their numbers at and near the northern and southern margins of this distribution indicate a more extensive range. On a temperature and depth basis a continuous northern distribution is likely from the Labrador area to off the mouth of the Bay of

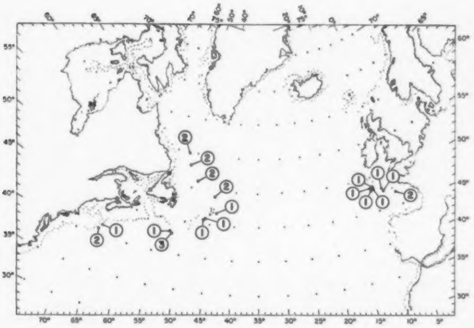

FIG. 1. Known distribution of *Bathyraja richardsoni* in North Atlantic. Numerals, numbers taken; depth contour, 183 m.

Biscay — through the areas off southern Greenland and south of the Iceland–Faroes Ridge.

Seventeen of the specimens were taken (and an additional six escaped near the ship) in 21 successful longline sets on bottom at 1810–2360 m with about 500–550 hooks per set, from Labrador to south of Georges Bank, and only one specimen in six similar sets over the range of the species but at 1370–1630 m.

North of the present range, in a bottom longline set off Fylla Bank at 1460 m (3.68 C) and another off Store Hellefiske Bank at 1650 m (–0.26 C), no *B. richardsoni* were taken. South of the present range, a longline set in Veatch Canyon, 39° 30′N, 69° 30′ 30″ W, at 2200 m caught no *B. richardsoni*.

In two 1-hr hauls on bottom between 1380 and 1580 m, one north of the Flemish Cap and the other off the Hudson Canyon, using a no. $^{4}_{1}$35 otter trawl with a 12-m headline, no *B. richardsoni* were caught. Nor has the species been taken in otter trawling with Biological Station research vessels over the past 20 years at intervals from 45–90 m down to about 750 m in the general area where it was captured in deeper water.

Known temperature records indicate that the northwest Atlantic specimens were taken in a narrow range of bottom temperatures between about 2.8 and 3.7 C.

Temperatures in the area of capture (Table 1) were between 3.26 and 3.85 C at depths from 1500 to 1770 m (in the deeper sets the hydrographic wire was too short to reach bottom). Bottom temperatures at *B. richardsoni* depths over its range of capture on the continental slope have been recorded as: 3.1–3.2 C off southern Labrador at 2000 m (Smith et al. 1937); 2.8–3.1 C at 2000–2500 m seaward off Flemish Cap and off the mid-eastern Grand Bank (Dietrich 1960; Movchan 1967); and 3.0–3.3 C at 2200 m in sections from southern Nova Scotia to off Delaware Bay (Iselin 1936). In the northeast Atlantic *B. richardsoni* were taken at bottom temperatures of 3.75–3.90 C (Forster 1968) and in depths of 2002–2542 m.

Morphometric Characteristics

The ranges of most body proportions of the northwest Atlantic specimens measured (Table 2, Fig. 2) are close to these proportions in the holotype and Plymouth specimens. For the few body proportions where the holotype or the Plymouth specimens are outside the range of those from the northwest Atlantic, the differences are minor and may be explained by the small number of specimens examined, the condition of the fish, or other common sources of variation.

In the small range between the smallest and largest male measured (all mature) there was little or no evidence of allometry. In the six females measured, with a much greater range and with the smallest three immature, there was evidence of negative allometry in the following proportions (percentages of length from snout to origin of first dorsal):

1. Total length, mm	950	1021	1317	1579	1692	1722
11. Snout: mid-length before orbits	14.3	15.4	13.6	14.2	12.3	12.6
12. Snout: mid-length to mid-pupils	16.7	17.5	15.8	16.2	14.3	14.5
13. Snout: mid-length before mouth	15.8	15.7	14.4	14.3	13.3	13.3
16. Interorbital width, least fleshy	12.1	12.0	11.9	11.6	10.9	11.0
17. Cornea: greatest horizontal diameter	2.4	2.3	2.0	2.0	1.9	1.7
19. Nostrils: shortest distance between	12.4	12.0	11.6	12.1	11.0	10.6
20. Mouth: width	–	13.2	13.0	12.5	12.5	11.4

The variety of form, the small number of fish measured, the occasional evidence of allometry in the measurement of females, and the lack of a considerable overlapping in length between the specimens of the two sexes offer difficulties in the close comparison of body proportions of males and females. However, many of the anterior proportions appear to be relatively greater in the female, and many of the posterior proportions relatively

TABLE 1. Records of capture and escapement of *Bathyraja richardsoni* in the northwest Atlantic, 1965–68.

Date of capture	Locality	Lat. N, long. W (midpoint of set); depth range (*m*)	Temp. (*C*)	No. of spines and scars	Specimen, length (*cm*) at sea, and sex
		Specimens captured			
Aug. 14, 1967	Hamilton Inlet Bank	54°52′15″; 51°59′30″; 2190–2220	3.34(1695)^{a}	20, 13	A 134 ♂, B 159 ♀
Aug. 15, 1967	E of Hawke Channel	53 01 00 ; 51 27 30 ; 2100–2270	3.61(1701)	19, 22	C 130 ♂, D 170 ♀
Apr. 15, 1966	Off NE Newfoundland Shelf	50 59 00 ; 48 56 45 ; 2070–2150	3.38(1690)	18, 18	E 143 ♂, F 133 ♀
July 14, 1965	N of Flemish Cap	49 02 52 ; 44 46 00 ; 2190	3.26(1770)	–	G124.3 ♂, H 129.4 ♂
Aug. 19, 1967	SE of Flemish Cap	46 48 00 ; 43 43 45 ; 2180–2360	3.42(1683)	18	I 174 ♀
Apr. 19, 1968	Off E Grand Bank	45 45 44 ; 46 28 45 ; 1370–1500	3.66(1555)	17	J 123+ ♂^{b}
Aug. 20, 1967	Off E Grand Bank	45 40 38 ; 46 40 15 ; 2080–2250	3.53(1679)	17	K 95.3 ♀
May 1, 1966	Off SW Grand Bank	43 24 20 ; 52 44 38 ; 1920–2140	3.63(1500)	18	L 108 ♂
Aug. 22, 1967	Off SW Grand Bank	43 03 30 ; 52 02 45 ; 1810–2010	3.68(1701)	16, 18, 18	M 134 ♂, N 131 ♂, O 120 ♂
Nov. 11, 1966	S of Browns Bank	41 45 15 ; 65 06 45 ; 2100–2190	3.67(1761)	19	P 130 ♂
Apr. 24, 1968	Off Georges Bank	41 11 45 ; 65 53 00 ; 2160–2230	3.85(1573)	16, 16	Q 154+ ♀^{c}, R 103 ♀
		Specimens brought to the surface close to the ship and lost			
Aug. 15, 1967	E of Hawke Channel	53 01 00 ; 51 27 30 ; 2100–2270	3.61(1701)	–	One 130–140^{d}
Aug. 18, 1967	N of Flemish Cap	49 03 30 ; 44 32 00 ; 2190–2270	3.32(1683)	–	Two 160–180^{d}
May 1, 1966	Off SW Grand Bank	43 24 20 ; 52 44 38 ; 1920–2140	3.63(1500)	–	One 120–130^{d}
Aug. 22, 1967	Off SW Grand Bank	43 03 30 ; 52 02 45 ; 1810–2010	3.68(1701)	–	Two 130–140^{d}
Apr. 24, 1968	Off Georges Bank	41 11 45 ; 65 53 00 ; 2160–2230	3.85(1573)	–	One 130–140 ♂^{d}

[a] Depth at which temperature was taken; in all but the set at 1370–1500 m, the hydrographic wire was too short to reach bottom.
[b] Tail regenerated at anterior beginning of first dorsal.
[c] Posterior end of tail broken.
[d] Estimated by technician-in-charge.

TABLE 2. Ranges (in parentheses, averages) of morphometric characteristics of seven male and six female *B. richardsoni* from the northwest Atlantic compared with those of the holotype from New Zealand (measurements from Garrick 1961) and of two specimens from the northeast Atlantic (Plymouth specimens, measurements from Forster 1965). All measurements except 1 and 2 expressed as percentages of length from snout to anterior origin of first dorsal.

Item no.	Body part	Northwest Atlantic specimens[a]		Holotype Female	Plymouth	
		Male	Female		Male	Female
1.	Total length, mm	1201–1422(1315)	950–1722(1380)	1331 +	1133	1455
2.	Length, snout to anterior origin 1st dorsal, mm	1089–1229(1176)	864–1549(1243)	1235	1036	1326
3.	Disc: length, snout to posterior end pectoral	59.5–62.5(60.6)	59.5–64.5(62.1)	65.2	61.6	64.7
4.	Length, snout to posterior end pelvic	74.1–80.1(76.9)	73.4–79.1(76.7)	–	–	–
5.	Disc: greatest width	73.6–78.4(76.2)	73.9–82.1(77.0)	77.6	75.7	75.7
6.	Disc: greatest thickness	5.3–7.1(6.3)	6.1–7.2(6.8)	ca. 8.2	ca. 7.7	ca. 8.1
7.	Tip snout to center cloaca	62.0–64.6(63.3)	63.5–67.8(65.9)	66.5	65.1	67.0
8.	Center cloaca to tip tail	44.8–50.4(47.8)[b]	43.4–47.6(45.1)	–	44.3	42.7
9.	Posterior border cloaca to tip tail	43.9–49.5(46.6)[b]	42.7–46.9(44.3)	–	–	–
10.	Center cloaca to anterior origin first dorsal	35.4–38.0(36.7)	32.2–36.5(34.1)	33.6	35.0	32.9
11.	Snout: midlength before orbits	12.2–13.3(12.7)	12.3–15.4(13.7)	14.9	14.0	15.9
12.	Snout: midlength to midpupils	14.4–15.7(15.0)	14.3–17.5(15.8)	–	–	–
13.	Snout: midlength before mouth	12.0–13.8(13.0)	13.3–15.8(14.5)	15.4	14.2	15.6
14.	Head: width across midpupils	26.1–32.7(28.7)	28.1–38.9(32.9)	–	–	–
15.	Interorbital width, least cartilaginous	6.9–8.3(7.5)	7.1–8.8(8.0)	–	–	–
16.	Interorbital width, least fleshy[c]	10.0–11.8(10.8)	10.9–12.1(11.6)	12.3	11.4	12.2
17.	Cornea: greatest horizontal diameter	2.1–2.5(2.3)	1.7–2.4(2.1)	1.9	2.4	1.9
18.	Spiracles: shortest distance between	11.1–12.6(11.9)	11.8–13.6(12.7)	14.1	11.8	13.6
19.	Nostrils: shortest distance between	10.0–11.6(10.8)	10.6–12.4(11.6)	12.0	12.0	13.2
20.	Mouth: width[d]	11.6–13.8(12.8)	11.4–13.2(12.5)	12.5	12.6	13.4
21.	Gill slits first pair: shortest distance between	20.0–23.1(21.3)	21.0–22.9(22.3)	23.5	22.7	23.3
22.	Gill slits fifth pair: shortest distance between	14.8–16.9(16.0)	17.0–18.9(17.9)	18.2	16.8	16.6
23.	Gill slits: greatest width first	1.5–1.9(1.7)	1.6–1.9(1.7)	2.1	2.0	1.6
24.	Gill slits: greatest width third	1.8–2.1(2.0)	1.8–2.2(2.0)	2.4	2.3	2.1
25.	Gill slits: greatest width fifth	1.4–1.8(1.6)	1.3–1.9(1.6)	2.0	1.9	1.8
26.	Pelvic fin: length from axil of pectoral	17.8–21.2(19.8)	16.1–17.9(17.1)	–	–	–
27.	Clasper: distance tip to tip pelvic fin	19.7–21.7(20.3)	– – –	–	–	–
28.	Clasper: total length to medial junction with tail	25.0–28.1(26.6)	– – –	–	–	–
29.	Tail: width at posterior tip pelvics	3.7–5.3(4.5)	4.2–5.0(4.7)	5.0	–	–
30.	Tail: width at origin first dorsal	1.3–1.8(1.5)	1.3–1.4(1.4)	1.7	–	–
31.	Posterior base second dorsal to tip tail	3.1–4.5(3.8)	2.8–4.2(3.5)	[e]	4.3	2.6
32.	Dorsals: space between	0–2.2(0.7)	0.2–1.7(0.8)	0.8	0.8	1.1
33.	First dorsal: greatest vertical height	2.0–2.8(2.3)	1.4–1.7(1.5)	1.6	1.5	1.5
34.	Second dorsal: greatest vertical height	1.7–2.4(2.0)	1.6–1.8(1.7)	[e]	2.0	1.5
35.	First dorsal: length of base	3.4–4.3(3.8)	3.2–4.1(3.5)	3.2	3.4	3.8
36.	Second dorsal: length of base	3.0–4.1(3.6)	2.8–3.9(3.4)	[e]	3.1	3.2
37.	Caudal fin: greatest vertical height	0.3–0.7(0.5)	0.3–0.5(0.4)	[e]	0.5	0.3
38.	Anterior angle (degrees)[f]	(82)86–92(89.0)	88–92(89.3)	ca. 90	–	–

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[a] All males measured were sexually mature. The three smaller females, 950–1317 mm TL were immature and the three larger ones 1579–1722 mm TL, were mature.

[b] Measurements of longest male (E, Table 1) affected by unusual length from posterior base of second dorsal to tip of tail and not included in range or average for three proportions affected by this measurement. For this specimen, item 8 = 52.9, item 9 = 51.2, and item 31 = 7.3.

[c] In my measurements, shortest distance between lateral edges of eyelids — usually somewhat anterior to center of eye.

[d] In my measurements, width between natural skin folds covering corners of mouth on each side.

[e] Unsuitable for this characteristic.

[f] Measured as in Bigelow and Schroeder (1953).

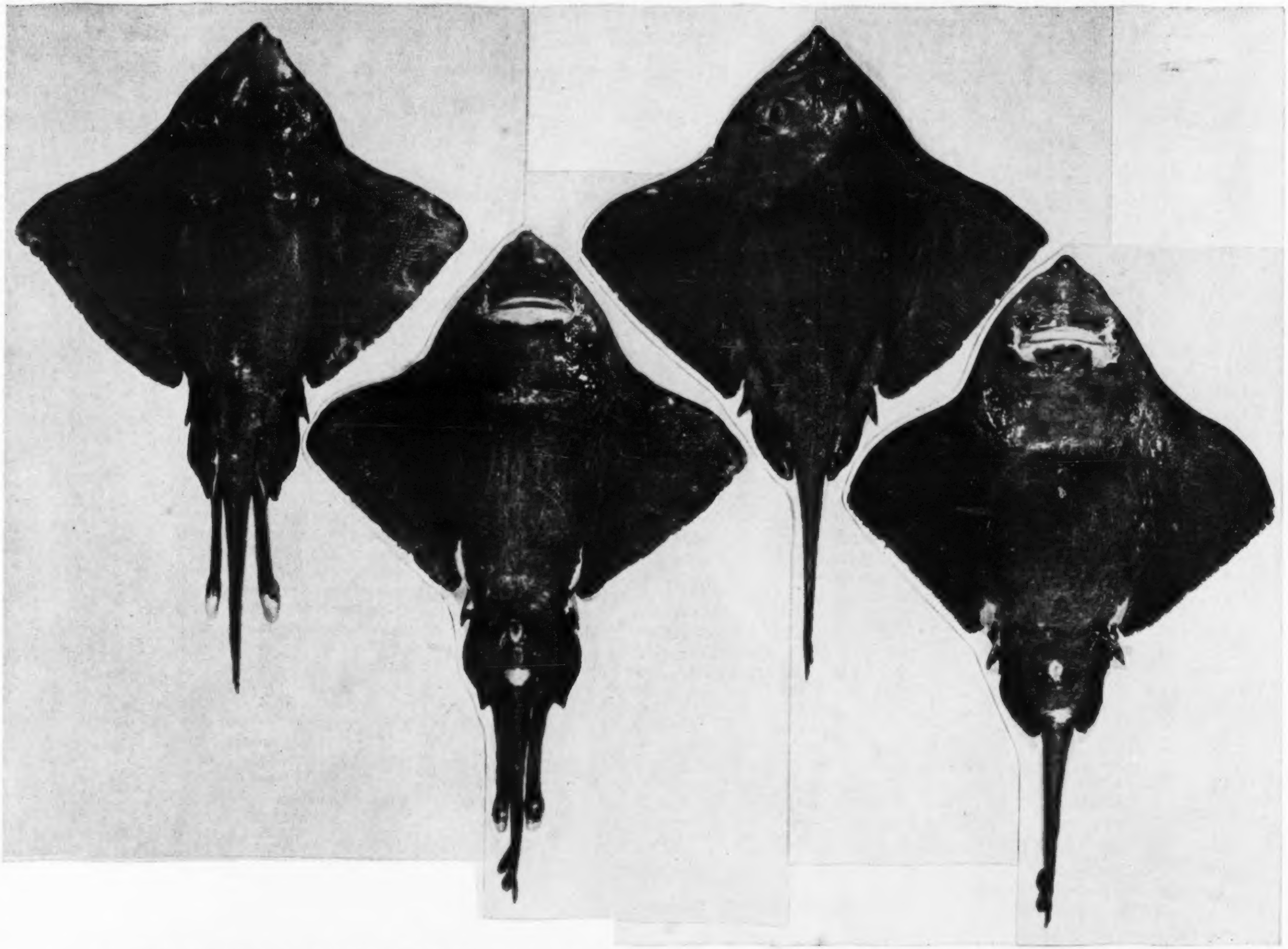

FIG. 2. Dorsal and ventral views of *B. richardsoni*: *left*, mature male (P, Table 1); *right*, immature females (R and K, Table 1).

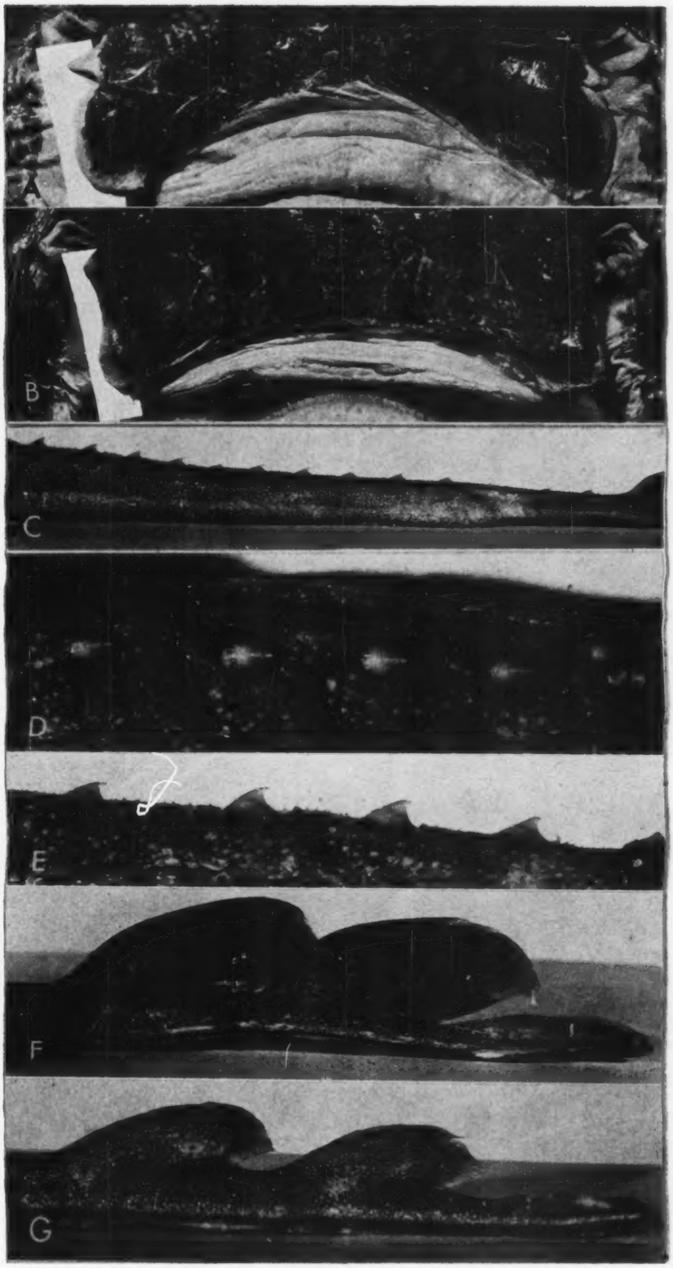

FIG. 3. Views of parts of *B. richardsoni*: A and B (P, F, Table 1), nasal curtains, × 0.6; C (K, Table 1), lateral view showing middorsal spines)fifth spine broken) of posterior part of tail to first dorsal, × 0.5; D and E, dorsal and lateral views of anterior part of C × 1.4; F and G (C, B, Table 1), lateral views of dorsal and caudal fins of mature male and mature female, × 0.7 and 0.6.

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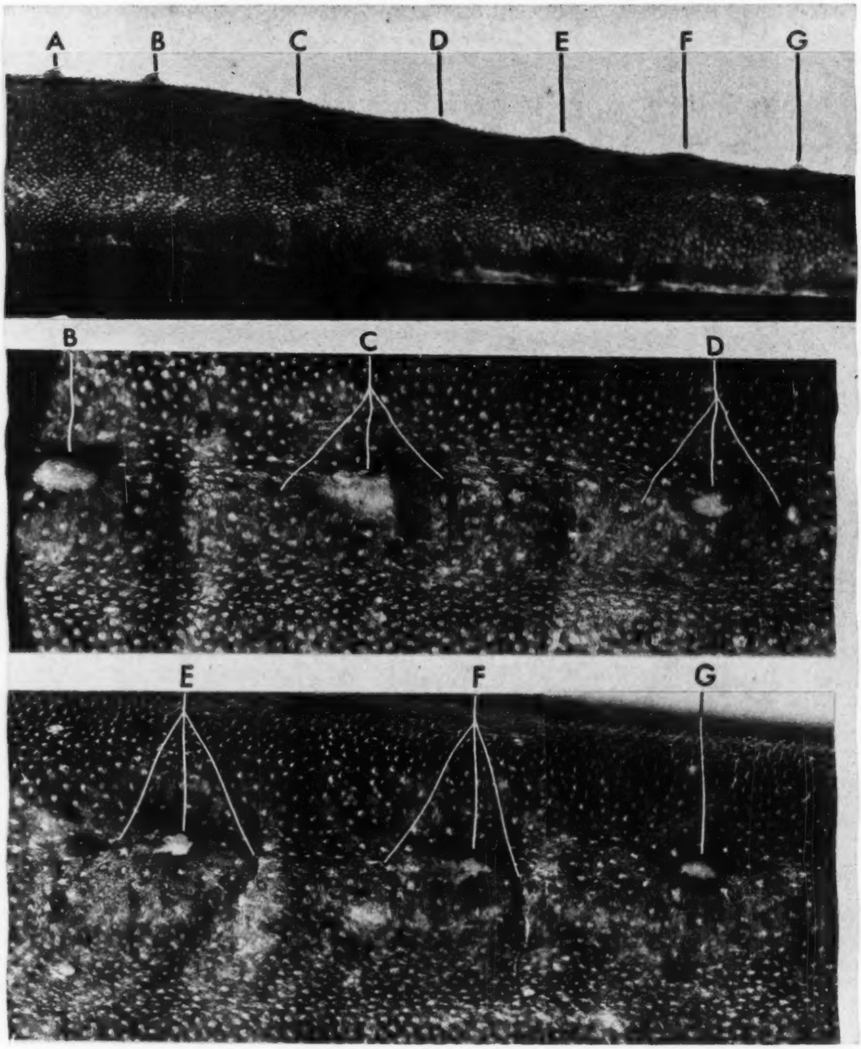

FIG. 4. *Above*, lateral view, × 0.9, and, *below*, enlarged dorsal views, × 2.0, of anterior region of tail of *B. richardsoni* (P, Table 1) to show (from anterior to posterior) two middorsal caudal spnies (A and B), four scars (C–F), some with traces of degenerate spines, and one small spine, (G).

TABLE 3. Weights and number characteristics of *B. richardsoni* from northwest Atlantic.

Specimen (Table 1)	Total length[a] (*mm*)	Whole weight[a] (*kg*)	Weight of liver at Station (% of whole weight)	No. middorsal spines on tail and no. rows of teeth	Max no. transverse rows alar spines
	Males				
L	1080(1094)[b]	– (9.3)	–	18; 32/25[k]	0(0)[l]
O	1200(1201)[c]	15.2(12.9)	13.4	18; 24/25	25(6)
J	1230+(1313)[cd]	14.1(13.2)	19.8	17; 23/19	31(5)
G	1243 –[c]	15.9 –	–	?; 26/16	27(6)
H	1294 –[c]	15.9 –	–	?; 24/21	28(8)
C	1300(1306)[c]	19.7(17.9)	23.0[e]	19; 21/19	26(6)
P	1300(1296)[c]	16.8(15.9)	17.9[f]	19; 30/23	27(6)
N	1310(1309)[c]	14.3(12.3)	12.9	18; 23/22	26(7)
A	1340(1331)[c]	18.4(16.3)	20.2[g]	20; 26/23	28(9)
M	1340(1338)[c]	17.9(15.9)	10.1	16;30/25	29(6)
E	1430(1422)[c]	– (19.1)	15.5	18; 25/23	30(9)
	Females				*Largest egg in ovary*
K	953(950)[b]	7.7(6.3)	–	17(31/26)	1.5/0.002[m](0.7)[n]
R	1030(1021)[b]	9.4(8.5)	14.0	16(31/26)	4/0.03(0.7)
F	1330(1317)[b]	– (19.7)	16.0	18(28/21)	10/0.5(36)
Q	1540+(1569)[cd]	29.5(27.7)	15.2	16(26/18)	–/56(312)
B	1590(1579)[c]	35.4(30.2)	16.8[h]	13(24/19)	–(351)
D	1700(1692)[c]	35.0(34.5)	13.8[i]	22(27/24)	–/136(631)
I	1740(1722)[c]	37.7(36.3)	17.2[j]	18(40/32)	–/55(379)

[a] At sea and (in parentheses) at Biological Station, lengths at sea being taken to the nearest centimeter.
[b] Immature.
[c] Mature.
[d] Total length calculated from distance from snout to anterior origin first dorsal.
Per cent fat in liver (acid hydrolysis) — e, 75.8; f, 69.7; g, 76.5; h, 74.4; i, 65.8; j, 74.0.
Vitamin A of liver oil, international units/g — e, 659; f, 70; g, 615; h, 412; i, 2106; j, 1041.
Millions of units of vitamin A in liver — e, 2.05; f, 0.14; g, 1.55; h, 1.55; i, 6.60; j, 4.82.
[k] Upper and lower.
[l] Maximum number of spines in a transverse row.
[m] Diameter (mm) and volume (cm³).
[n] Weight of two shell glands (g).

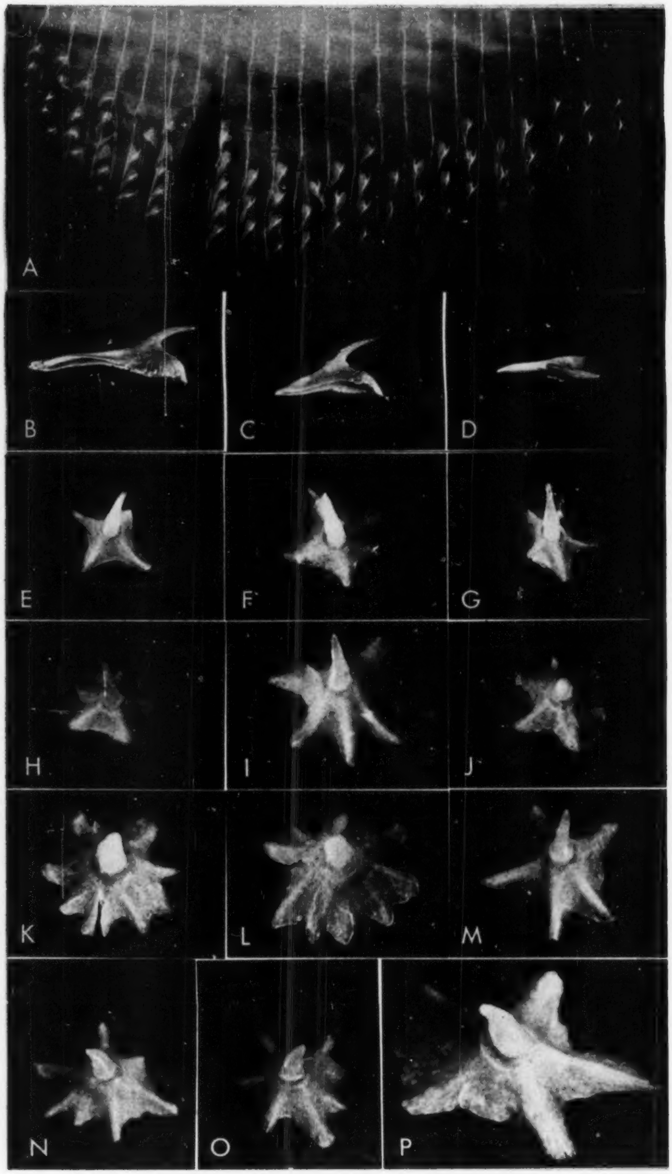

FIG. 5. Alar spines (A–D) and dermal denticles (E–P, × 23) of *B. richardsoni*: A, radiograph of spines (anterior at left), × 0.5, of mature male (O, Table 1); B and C, lateral, and D, dorsal, views × 2, of spines of mature male (E, Table 1); E–H, denticles from middorsal area at greatest width; I–L, from dorsal surface near tip of snout; M–P, from dorsal anterior edge of pectoral, about midway at pectoral edge between line through spiracles and tip of pectoral at greatest width.

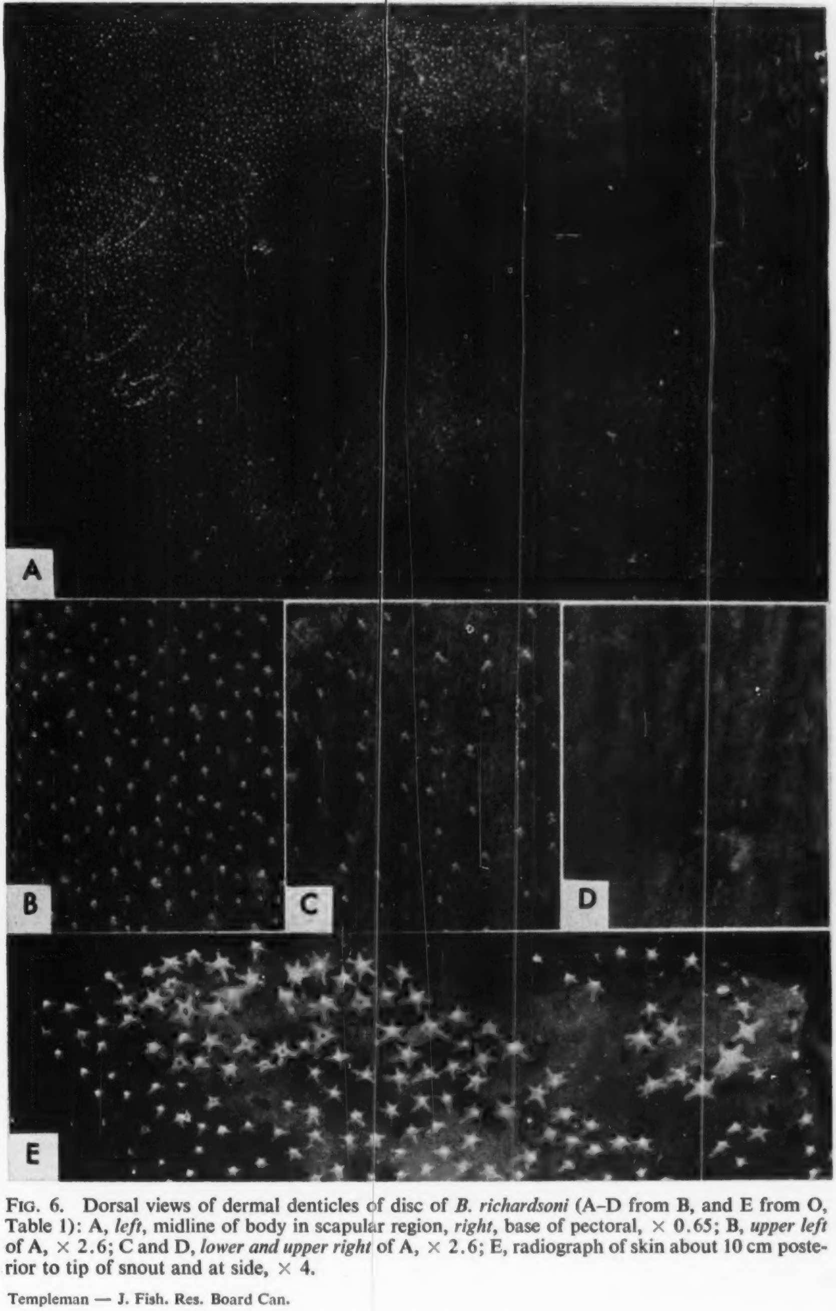

FIG. 6. Dorsal views of dermal denticles of disc of *B. richardsoni* (A–D from B, and E from O, Table 1): A, *left*, midline of body in scapular region, *right*, base of pectoral, × 0.65; B, *upper left* of A, × 2.6; C and D, *lower and upper right* of A, × 2.6; E, radiograph of skin about 10 cm posterior to tip of snout and at side, × 4.

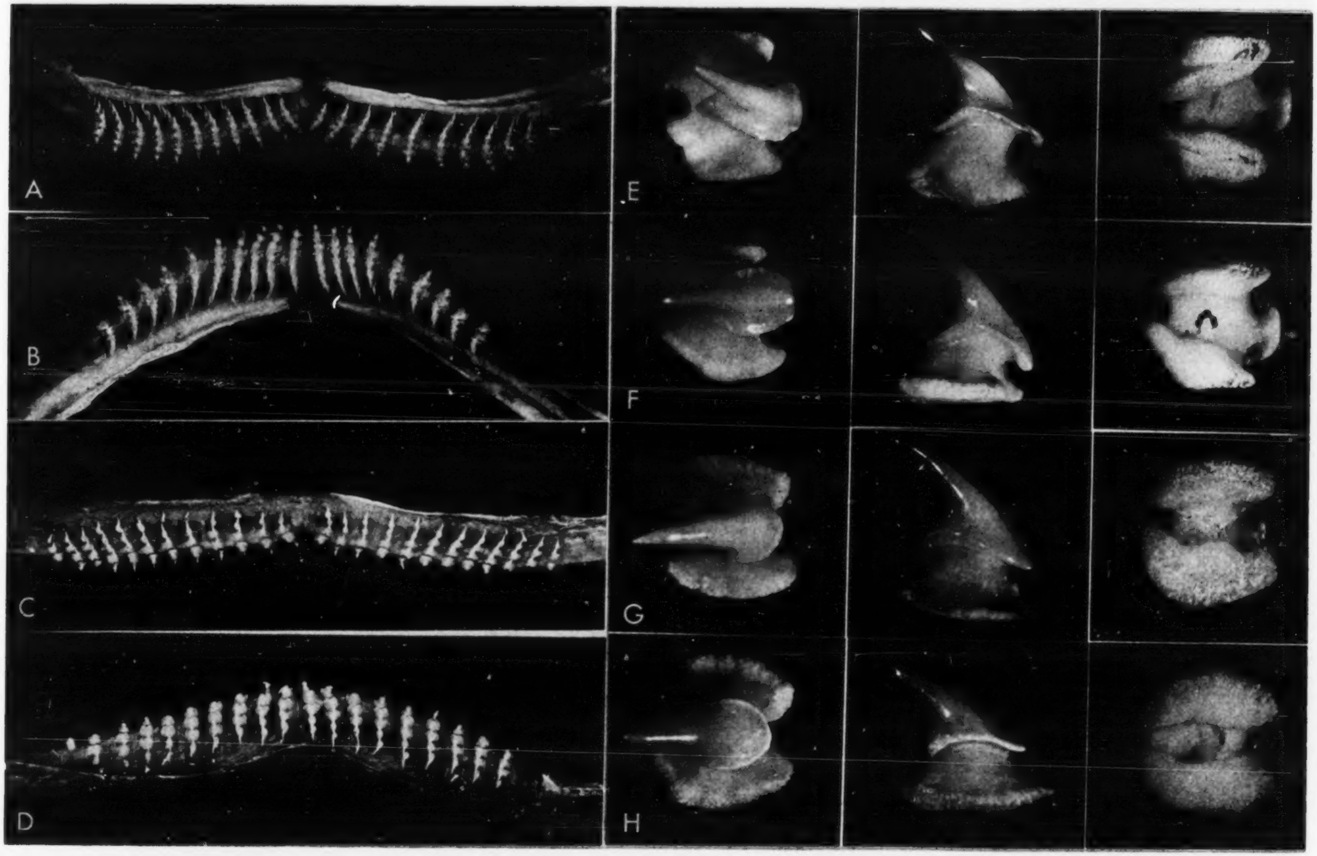

FIG. 7. A–D, dorsal views of tooth rows and tooth-bearing part of jaw of *B. richardsoni:* A and B (C, Table 1), upper and lower jaws of mature male, × 0.6 and 0.8; C and D (B, Table 1), upper and lower jaws of mature female, × 0.6 and 0.7. E–H, upper, lateral, and basal views (× 7) of teeth of lower jaw of *B. richardsoni:* E and F (H, C, Table 1), from mature males 129 and 131 cm TL; G and H (B, D, Table 1), from mature females 158 and 169 cm TL.

greater in the male. These characteristics, either in the averages or in the overlapping parts of the ranges, are best demonstrated for the following which appear to be greater in the female: snout length; shortest distances between spiracles and between fifth pair of gill slits; head width across mid-pupils; and distance from tip of snout to center of cloaca. Conversely, the following appear to be greater in the male: distances from center of cloaca to tip of tail and to origin of first dorsal and from posterior border of cloaca to tip of tail; pelvic fin length; and height of dorsals.

The claspers reach almost to the first dorsal (Fig. 2).

As in Forster's (1965) specimens, the triangular processes of the nasal curtain in my specimens are usually better developed (Fig. 3A) than in Garrick's (1961) holotype. However, there is considerable variety, and in one of the northwest Atlantic specimens (Fig. 3B) the triangular nasal process is reduced to a form resembling that of the holotype.

Spines, Dermal Denticles, and Teeth

Middorsal caudal and alar spines — A median dorsal row of spines is found on the tail region of *B. richardsoni* (Fig. 2–4) although Garrick (1961) described oval fleshy structures in this location, some with a central tubercle of enamel, and Forster (1965) described similar tubercles but without the oval raised areas. These spines are of moderate size and are considerably smaller than those found in the similarly large skate *B. spinicauda*. When uninjured, mechanically or by age, they are sharp pointed (Fig. 3).

I conclude that the middorsal spines of *B. richardsoni* from the northwest Atlantic are similar in shape and number to those from the northeast Atlantic, and that in these respects the New Zealand holotype very likely differs only in having lost its middorsal spines at some time before capture.

As is usual in skate species possessing them some of these middorsal spines are occasionally absent in *B. richardsoni* and are represented only by scars, sometimes with a raised ridge and sometimes low and flat. Typically there are one or two rings of enlarged dermal denticles in the outer border of the scar area and these may also be present around the bases of normal spines. Often the central area of the scar is bare of denticles, and may show whitened areas in the region formerly covered by the spine. However, dermal denticles sometimes invade the whole scar area. Occasionally small spines may be present at the top of a raised ridge or centrally in a scar area, and small degenerate parts of spines may be present on some portion of the raised ridge. When identifiable spines were present, even though small they were counted as spines and not scars (Fig. 4).

In 16 *B. richardsoni* in which middorsal spines and scars were counted, the number of scars varied from zero in three specimens to 9 of 18 spines and scars in the largest female and 12 of 18 in a large male. The number of scars increased from the smaller to the larger sizes in females but not in males, for which the range of fish sizes was less (Table 3). With the small numbers involved I can find no reason to conclude that the number of middorsal spines and scars varies greatly with length of fish (Table 3) or with latitude (Table 1). Most *B. richardsoni* have a space between the bases of the dorsals (Table 2), but no spine is present in the space.

Garrick (1961) does not mention the number of middorsal caudal fleshy structures which were present instead of spines in the holotype, but shows 20 of them in his diagram and one empty space, a total of 21.

Forster (1965) says that the Plymouth female has 12 tubercles similar to those of Garrick's specimen, but that there are no ovoid raised areas and in addition there are three scars in places where tubercles may have existed. He says also that the male from Plymouth has 13 tubercles of slightly larger size and possibly one or two scars or open areas representing lost tubercles. At the British Museum (Natural History) I examined the two Plymouth specimens, which were the first two captured in the northeast Atlantic. Both of these skates have a median row of small spines in the middorsal line of the tail. In the male I counted 15 including a scar and an open area indicating a missing spine. In the female I estimated 16, including four scars.

Of the 11 males, all except the smallest are mature and have alar spines, pointing obliquely posteromedially and ranging from 25–31 transverse rows and a maximum number in a transverse row from five to nine (Fig. 5, Table 3).

Garrick's (1961) holotype is a female but one of Forster's (1965) specimens is a mature male with alar spines in rows up to six deep, and hence falls within the range for my specimens. Forster's figure shows about 23–24 transverse rows of alar spines, which is close to the lower range of my specimens and examination of the specimen might show one or two more indications of rows.

The specimens from the northwest Atlantic are, like the holotype and those from the northeast Atlantic, completely devoid of large spines other than those described in this subsection.

Dermal denticles — Small, more or less stellate spines (dermal denticles), usually barely rising above the skin surface, occur in varying numbers on upper and lower surfaces of specimens (Fig. 5, 6) from the northwest Atlantic. The dermal denticles vary in size and shape. In the dorsal central area of the disc they are mainly moderate in size and with four- to six-pointed bases. In the two skates checked, near the central part of the pectoral girdle area, in one the dermal denticles had mainly four-pointed bases and in the other mainly five-pointed. In some other areas, e.g. dorsally at the tip of the snout and at the anterior edge of the pectoral, some of them may be larger and have as many as seven to nine points in the base.

The upper and lower surfaces of the disc and tail of the holotype are covered with dermal denticles. The lips, the distal margins of the fins, and the tip of the tail are the only smooth regions. On the ventral surface, the denticles are somewhat sparser than they are dorsally (Garrick 1961). Forster (1965) says that in his first two specimens from the northeast Atlantic the dermal denticles are spread evenly over the whole dorsal surface and also ventrally in the abdominal area, though in the pectoral area they are distinctly scarce.

In the specimens from the northwest Atlantic, the form of the denticles and their presence on the upper and lower surfaces agree with the situation in the holotype and northeast Atlantic specimens, especially in the tail region. However, the dermal denticles do not cover the entire dorsal surface but are thickly localized in certain areas, especially middorsally, and scarce to absent on the outer parts of the body cavity and at the bases of the pectorals. On the ventral surface, dermal denticles are localized, only occasionally plentiful and often scarce to very scarce. There is thus considerable variability in dermal denticle numbers and distribution and the study would be improved if smaller specimens were available. Because of these differences, I shall describe the dermal denticle distribution in northwest Atlantic specimens in some detail.

Dorsal surface — Dermal denticles set closely together cover the upper surface of the tail and the sides of the dorsal fins, but are absent on the thin posterior fringes of the dorsals and on the caudal fin except at the base.

In males the denticles are usually distributed as follows: The tail is covered with denticles. From the base of the tail a band of thickly set denticles extends forward along the midline of the disc, gradually spreading until at the scapular region it is about three times as wide as at the base of the tail. This band narrows rapidly in the neck area in front of the scapular region, expands again to cover the area between the spiracles and the interorbital area, and thins out over the snout. On the disc the denticles become gradually scarcer from the central area to the outer part of the body cavity (Fig. 2, right, dorsal; 6) and are absent or extremely rare from the base of the pectorals in a wide triangle extending to near the alar spines, where they become plentiful again. They extend outward from the alar spines and are thickly set along the anterior edge of the pectoral from just in front of the lateral tip of the pectoral forward along the sides of the head, often becoming scarcer on the head. They are scarce to absent along the outer posterior border of the pectorals from the tips backwards, and absent in the axils of the pectorals and pelvics. On the pelvics they range from moderately plentiful through to thinly distributed to absent on the outer fringes. Claspers are devoid of denticles except dorsally and laterally on the grey and white swollen area near but not at the posterior tips.

The distribution of denticles on the dorsal surface is usually similar in the females to that described for the males, apart from the references to the claspers and considering that the distribution of denticles in relation to the alar spines is to be understood for the females in relation to this same area. As in the males, the denticles are usually scarce to absent dorsally in those areas of greatest flexibility where the denticles might rub the skin.

Ventral surface — In the smallest male, which is immature, dermal denticles are numerous on the posterior half of the tail. A band of denticles about 4–6 cm wide runs forward on each side from the anterior base of the pelvic fin forward along the outer part to the anterior end of the body cavity. There are some denticles in front of and lateral to the mouth, and elsewhere denticles are scarce to absent.

In mature males, the denticles are extremely scarce on the ventral surface of the disc, usually with only single ones or very small numbers in a few local spots and large areas without any. The denticles below the alar spines, though not always present, are sometimes moderately large. There are sometimes denticles between or near the nostrils. Denticles are scarce to absent: over the whole pelvic area; from the cloaca to several centimeters posterior to the usually white area near the base of the tail and in the midline of the tail except from below the area of the dorsals backward. They are moderately plentiful along the lateral borders of the ventral surface of the tail but more plentiful anteriorly and scarcer on the posterior half of the tail. There is sometimes a group of scarce denticles near the base and extending to or beyond the middle of the clasper. Denticles are usually numerous but sometimes scarce towards the tip of the clasper especially on the grey and white areas at the base and lateral edge but not at the tip of the swollen part of the clasper.

In females the distribution of denticles on the tail is essentially similar to that in males. The denticles are relatively much more plentiful ventrally on the disc in larger than in smaller specimens. In immature females, denticles are extremely scarce to very scarce on the disc and absent over large areas of the disc. A few are present between snout and mouth. In mature females, the denticles in the area covering the abdominal cavity vary from: scarce in one specimen to numerous in three others; over the pectorals from scarce near the base and scarcer toward the edges to scarce at the base and more numerous toward the outer edges, but scarce or absent along the outer border; and from scarce to numerous around the mouth and on snout and gill slit regions.

Teeth — The number of transverse rows of teeth in the specimens from the northwest Atlantic (Fig. 7, Table 3) is greater in the upper jaw, 21–32 (40), than in the lower, 16–26(32). Omitting the female with the largest number of rows (40/32), ranges for males (upper, 21–32; lower, 16–25) are approximately similar to those for females (upper, 24–31; lower, 18–26). Also, there is no apparent relationship between the size of the fish and the number of rows of teeth, although the one with the largest number is the largest fish, or between the number of rows of teeth and the latitude.

In a tooth row, including the hard teeth and the softer developing teeth readily visible to the naked eye, as many as 11 teeth were counted in the upper jaw and 9 and 10 in the lower (in specimens G and H).

Garrick's number of rows of teeth for the holotype, 31/28, and Forster's 27/21 and 26/21 for northeast Atlantic specimens, are included in the range of the northwest Atlantic specimens, and agree in the larger number of teeth in the upper than in the lower jaw.

In describing the teeth I shall take the cusp as the enamel-covered section and the base as the supporting structure.

For the four mature males (C, G, H, O) and the one immature and the two mature females (R, B, D) whose teeth were removed and examined in detail, the following statements may be made: In mature males and the immature female but not in mature females, the rounded overhanging tip of the base of the cusp opposite to the mouth tends to be bent downward. In males but not in females this overhanging part of the base of the cusp usually extends to or beyond the base of the tooth. In males the lateral sides of the tooth bases tend to be angular in most teeth whereas in the females the lateral sides of the bases tend to be more rounded (Fig. 7). Only the larger developed teeth have been considered.

Although the teeth figured by Garrick (1961) for the holotype are generally similar to those of my specimens, they show the base of of the cusp pointed in the direction away from the mouth and rounded in the opposite direction below the point of the cusp. The teeth of the northwest Atlantic specimens are opposite in having the more rounded end of the base of the cusp in the direction away from the mouth and a much more strongly pointed end than in Garrick's illustration in the part of the base of the cusp below the point of the cusp (Fig. 7E, 7F).

At my request Garrick has reexamined the teeth of the holotype and finds (personal communication) that they are similar to those of the northwest Atlantic specimens in having the base of the cusp pointed sharply below the point of the cusp. Garrick has also sent me a tooth of the holotype and it is similar to those of the western Atlantic specimens.

Also the base of the cusp overhangs the base of the tooth only at the rounded end opposite the mouth (Fig. 7) and not toward the mouth underneath the sharp part of the cusp as is indicated in a drawing by Garrick. The tooth of the holotype provided by Garrick is like those from the northwest Atlantic in this respect. In this area below the pointed part of the base of the cusp, the junction of the cusp with the base of the tooth is translucent.

COLOR

There are some minor differences in color pattern between individuals but the range within the species is not great. Allowing for a small range of variation the northwest Atlantic specimens are similar in color to the holotype.

The background color of the dorsal surface for the northwest Atlantic specimens was recorded as pale grey, grey, brownish-grey, and light brown, or, usually, brownish-grey or greyish-brown. Some white is usually present in the axils of the pectorals and often in the posterior axils of the pelvics. The claspers have white posterior tips and white is usually present dorsally near the base. An occasional white or black spot is present on the disc (Fig. 2).

The background color of the ventral surface is similar to that for the dorsal surface except that some specimens are dark grey on the ventral and grey or light grey on the dorsal surface. The following areas are white: around mouth, extending to nostrils; a ring around cloaca; a band at base of tail though it is occasionally very much reduced or absent; posterior tips of claspers and axils of pectorals; sometimes, tips of anterior lobes of pelvics; occasionally, a patch posteriorly on tail and on pectorals; and, usually, a narrow band on anterior border of each gill slit and, occasionally, on posterior border. After preservation, about half show little or no difference in depth of color on the dorsal and ventral surfaces whereas the remainder are slightly darker ventrally especially on the outer part of the pectoral.

Garrick (1961) describes the holotype in life as light to darker grey above with darker grey on the ventral surface and light areas ventrally similar to those I have described, and in formalin the background color as slightly brownish-grey. Forster (1965) describes his Plymouth specimens as light brown above and below, with white areas similar to those of the New Zealand and northwest Atlantic specimens, but his male skate lacked the white tips of the claspers, the white band at the base of the tail and white at the axils of the pectorals.

Conclusions Reading Species

The northwest Atlantic specimens have the same appearance and body proportions as the holotype and individuals of *B. richardsoni* from the eastern Atlantic. The ranges of middorsal spine and toothrow numbers for the northwest Atlantic specimens include those of the holotype and of northeast Atlantic specimens. In the specimens from the northwest Atlantic, there is much variation in distribution and abundance of dermal denticles on the ventral surface, in relation to sex, size, and maturity and to the holotype, which is a mature female. Further evaluation of these differences in relation to possible species differences must await the capture and study of a greater variety of sizes of both sexes from New Zealand. Meanwhile, the northwest Atlantic specimens can be called *Bathyraja richardsoni*.

The only other large skate known from the northwest Atlantic and resembling *B. richardsoni* is *Bathyraja spinicauda*, which differs from *B. richardsoni* mainly in the following respects (remarks applicable to *B. spinicauda*): a general lack of dermal denticles on ventral surface (except at margins of tail); whitish color on ventral surface; larger middorsal caudal spines; presence of a middorsal spine between dorsals; a much smaller interorbital distance; the much longer snout, the longer tail, and narrower distances between gill slits, spiracles, and nostrils (compare body proportions in Table 2 with those of *B. spinicauda* in Bigelow and Schroeder 1953); and more predorsal caudal vertebrae and pectoral radials (Stehmann 1970; Templeman 1973).

WEIGHT–LENGTH

For the logarithmic plot of total lengths at sea against whole weights at sea available (Fig. 8) all nine fish of intermediate lengths are males whereas the two at the smaller and the four at the greater lengths are females. Because adults of both sexes and the smallest two females, which are immature, fall approximately on the same line there is no need in these small numbers to assume weight differences due to sex or stage of sexual maturity.

The weight–length regression equation for sea total lengths in centimeters and weights in grams, computed by the method of least squares for fresh specimens, is Log $W = -1.4961 + 2.7109 \log L$ or in the common form $W = 0.03191\ L^{2.7109}$.

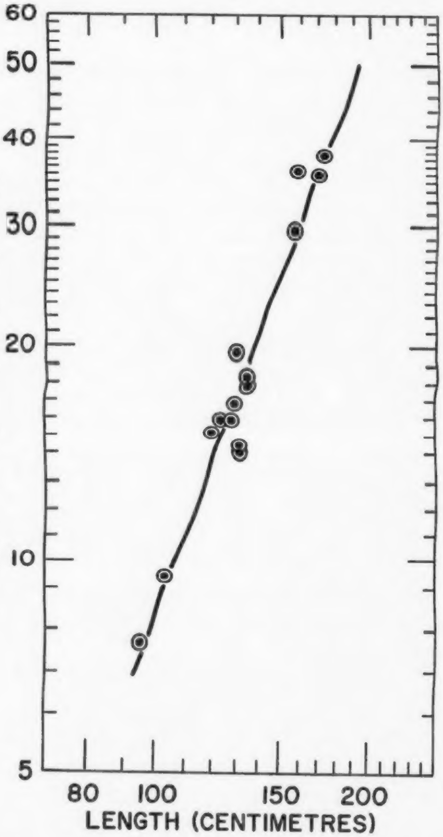

FIG. 8. Weight–length relationships of *B. richardsoni* from northwest Atlantic (sea-fresh whole weights and lengths available).

Although the sample is small, the data fit the log-log line very well. As weight at sea, taken soon after capture, usually differed considerably from that at the Biological Station, after freezing and thawing in ice (Table 3), the station weights were not used for Fig. 8.

LIVER WEIGHT, FATNESS, AND VITAMIN A

Livers were large, ranging from 10.1 to 23.0% of the whole weight at the Biological Station, and contained from 65.8 to 76.5% fat. Vitamin A values were very low, 70–2106 IU/gram of oil and 0.14–6.60 million IU/liver. In the few specimens examined, the usual effect of increased vitamin A per gram of oil and of total vitamin A in the liver with increase in age and size was shown in the considerably greater values for the largest two fish (Table 3).

SEXUAL MATURITY

Through all the specimens obtained are large, sexual maturity apparently begins at a large size. The one immature is 1094 mm TL and has no alar spines; small soft claspers have a total length of 10.1% of the distance from snout to first dorsal and extend beyond the tip of the pelvic fin only 4.0% of this distance.

The 10 mature males are 1201–1422 mm TL and have five to nine alar spines in a transverse row (Table 3), long hard claspers (Table 2), and large and coiled vasa deferentia, with much milt in the epididymus in two cases and in the vasa deferentia in the remainder.

For the two smaller immature females, 950 and 1021 mm TL the largest eggs in the ovary are not more than 2 mm in diameter in the smaller and 4 mm in diameter in the larger. For the third, 1317 mm TL, the largest egg diameter is 10 mm, the volume 0.5 cm^3, and the total weight of the two shell glands 36 g. For all four of the mature females, 1569–1722 cm TL, the eggs were large and of mature size, but owing to the freezing and thawing the largest of them were broken. The eggs which could be measured ranged from 56 to 136 cm^3 in volume. The oviducts and shell glands were large and of mature size. The total weight of both shell glands ranged from 312 to 631 g (Table 3). No egg capsules were present.

FOOD

Only 4 of the 18 stomachs of the specimens from the northwest Atlantic contained food. One was everted and one partly everted. Specimen K had 130 cm^3 of fish remnants, 5 cm^3 of pelagic shrimp, and 1 cm^3 of small whelks. Specimen F had a large redfish, apparently *Sebastes mentella*, about 45 cm, with the head gone (666 cm^3), specimen M had a well-digested redfish of about 40 cm (630 deepsea red shrimp, *Pasiphaea tarda* (21 cm^3)), and a 20-cm^3 portion of a giant alcyonarian, presumably *Paragorgia arborea*. Specimen D had the remains of two well-digested fish (170 cm^3) in its stomach. From this small evidence, in line with its sharp teeth and large size, by far the greatest portion of the food appears to be fish with, as is usual for skates, some shrimp and bottom invertebrates. The fish whose stomachs contained food came from a depth range of 1740–2300 m (Table 1).

PARASITES

Specimen C, from off southern Labrador, had 11 adult female copepods, usually with egg sacs, attached to the gill filaments of gill slits 1–4 from the anterior end (4, 2, 4, 1, respectively). One of these had the posterior part of the body and the egg sacs projecting through the fourth gill slit on the right side. The remainder were attached to gill filaments opposite or close to the branchial openings to the exterior. The gills of four other specimens examined in detail (B, D, O, and Q), had no copepods attached to the gills. The remainder were examined through the branchial openings and no additional copepods were seen, but some may have been hidden because the branchial openings are small in relation to the size of the gills. These copepods were examined by Dr Z. Kabata and tentatively identified as *Lernaeopodina longimana* (Olsson 1896).

Five of 14 stomachs examined contained flukes (C,3; E,1; L,5; O,9; and Q,1) and 6 of 16 intestines (C, L, F, N, O, R) contained tapeworm parasites. Ten of the flukes measured 66–79 mm in a relaxed condition and three, 32–47 mm. The tapeworms were large. These fluke and tapeworm parasites were examined by Mr S. Prudhoe of the Zoology Department, British Museum (Natural History) and he says (personal communication November 1968) that the trematodes appear to be *Otodistomum veliporum* (Creplin 1837) and the cestodes *Onchobothrium pseudouncinatum* Beauchamp 1905. The trematode has a more or less cosmopolitan distribution among various elasmobranchs and was reported by Templeman (1965) from the deepwater skate *Raja jenseni* of the northwest Atlantic. Prudhoe says that the cestode has previously been found only in rays of the North Atlantic.

The flukes and tapeworms were found in specimens from as far north as Hawke Channel, Labrador, latitude 53°01′N, to off Georges Bank, latitude 41°11′45″N (Table 1).

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Degradation of the Lampricide 3-Trifluoromethyl-4-Nitrophenol by Bottom Sediments[1,2]

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BOTHWELL, M. L., A. M. BEETON, AND J. J. LECH. 1973. Degradation of the lampricide 3-trifluoromethyl-4-nitrophenol by bottom sediments. J. Fish. Res. Board Can. 30: 1841–1846.

At low oxygen tensions in sediment–water aquaria systems, concentrations of 3-trifluoromethyl-4-nitrophenol (TFM) in the range 5–10 mg/liter were reduced to 3-trifluoromethyl-4-aminophenol (RTFM) in 5–20 days. This reduction resulted in loss of the characteristic yellow color of TFM as measured by the optical density at 395 nm. The reduced form was apparently stable, although inconclusive evidence suggested that some additional breakdown of RTFM may have occurred within 3 months under anoxic conditions. Under aerobic conditions, no significant degradation of TFM was observed for periods of up to 2.5 months. Sorption of TFM by sediments was observed to some extent and appeared to vary with the sediment source.

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A de faibles tensions d'oxygène dans des systèmes sédiment–eau en aquarium, les teneurs en 3-trifluorométhyl-4-nitrophénol (TFM) dans l'intervalle de 5 à 10 mg/litre sont réduites en 3-trifluorométhyl-4-aminophénol (RTFM) en l'espace de 5 à 20 jours. Cette réduction entraîne la perte de coloration jaune caractéristique du TFM, telle que mesurée par la densité optique à 395 nm. La forme réduite est assez stable, bien qu'on ait des indications encore non concluantes qu'une certaine dégradation additionnelle du RTFM se soit produite en dedans de 3 mois, dans des conditions anoxiques. En milieu aérobie, il ne se produit aucune dégradation marquée du TFM pendant des périodes allant jusqu'à 2.5 mois. Les sédiments absorbent une certaine quantité de TFM, variable selon la source du sédiment.

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THIS paper describes a series of experiments involving the incubation of ^{14}C labelled 3-trifluoromethyl-4-nitrophenol (TFM) in different sediment–water aquaria systems in an attempt to determine the stability of TFM and the degradation products of TFM. In the only previous investigation on microbial degradation of TFM, the optical density at 395 nm was used as a quantitative measure of the compound and loss of color at 395 nm, as an indicator of degradation of the molecule (Kempe 1973). This indicator, however, provides an inadequate description of TFM degradation. The main purpose of the present investigation was to determine what alterations of TFM were associated with the loss of optical density at 395 nm observed by Kempe, and what role oxygen tension played in this process. Consequently, we used mud–water incubation systems similar to those described by Kempe (1973). Unlike Kempe's study however, we monitored and controlled oxygen concentrations. The use of ^{14}C labelled TFM in conjunction with thin-layer and gas chromatography enabled precise identification of TFM and TFM derivatives. We also used bactericides (formalin and phenol) to distinguish between microbial and possible abiotic alterations of TFM.

Materials and Methods

Three experiments were designed to test degradation to TFM under different conditions. The variables between experiments were the sediment source, the sedi-

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ment to water ratio, the incubation temperature, the oxygen tension, the degree of organic enrichment, and inclusion of bactericidal controls in the second and third experiment.

In all cases the sediments were sieved through a 595-μm mesh screen (U.S. Standard Sieve no. 30) before being added to the incubation vessels. Water collected simultaneously with the sediments was used in every aquarium. All incubations were carried out in the dark to preclude possible photochemical degradation.

Sediment for the first experiment was collected by scraping the upper 2–3 cm from the bottom of the Milwaukee River, Ozaukee County. Twelve hundred grams of mud were placed in each of two 20-liter carboys. Fifty-gram amounts were added as an inoculum to two other 20-liter carboys and all four bottles were filled with river water. A mixture of unlabelled and ^{14}C (ring UL) TFM was added to one of the bottles with sediment and to one of the bottles with the bacterial inoculum, so that the initial concentration and radioactivity in each was about 7×10^5 dpm/5 mg TFM per liter. The remaining two carboys served as controls for optical density readings. Magnetic stirrers kept the solution slowly mixing during the entire experimental period. Incubations were carried out at 15 C. Oxygen concentrations were never allowed to drop below 3 mg/liter during the initial phase of this experiment and were maintained by bubbling with compressed air at 2-week intervals.

After an incubation period of 2.5 months, the four bottles were enriched with organics to promote bacterial growth. Additions of sucrose (200 g), nutrient broth (50 g), and yeast extract (5 g) were made to each carboy.

In the second experiment, two other sediment types were tested for TFM degradation capability under aerobic and anaerobic conditions. These sediments were collected with a Ponar grab from a station on Lake Michigan about 13 miles offshore and from a station in the Milwaukee Harbor. Seven 6-liter Erlenmeyer flasks, each containing 550 g of sediment, served as incubation vessels. Four of the flasks contained the offshore sediments and open lake water and were maintained under aerobic conditions by continuous aeration with compressed air. Three of the flasks contained the harbor sediments and harbor water and were allowed to go anaerobic after sealing with rubber stoppers. Two flasks, one of the aerobic and one of the anaerobic series, were initially sterilized by autoclaving.

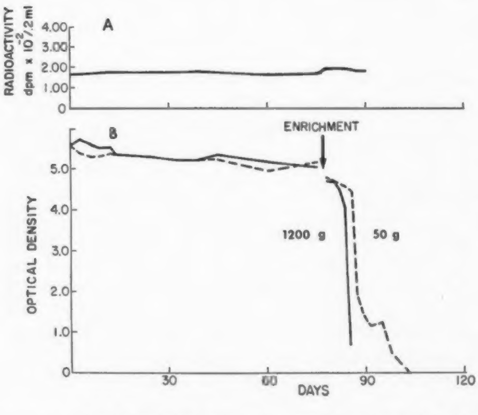

FIG. 1. Radioactivity of supernatant for both bottles containing ^{14}C-TFM in experiment 1 (A), and optical densities at 395 nm, 1 cm, of supernatants for two bottles with different amounts of sediment (B). Organics added on day 75.

A mixture of unlabelled and labelled TFM was added to the flasks with initial amounts of 1×10^6 dpm/10 mg TFM per liter in each. The flasks were incubated at room temperature for 2.5 months. On day 12, additions of formalin were made to the "sterile" controls.

The third experiment was designed to test the effect of phenol in aerobic and anaerobic TFM incubation systems. Four 1-liter Erlenmeyer flasks, each containing harbor water and 169 g of sediment from the Milwaukee Harbor, were set up as described above, two being aerobic and two an aerobic. One aerobic and one anaerobic system contained 25 g/liter of phenol. TFM, 1×10^6 dpm/6 mg per liter, was added to each flask and the systems were allowed to incubate for 29 days at room temperature.

Oxygen tension, optical density, and radioactivity of the supernatant fluid in all TFM containing bottles of each experiment were monitored periodically. Oxygen determinations were made with the unmodified Winkler technique (Strickland and Parsons 1968). Optical density readings at 395 nm were made on 3.8-ml aliquots at *p*H values raised above 8.0 by addition of 0.2 ml of 1N sodium hydroxide. Radioactivity of the supernatant was determined by liquid scintillation counting of 0.2-ml aliquots in 10 ml of Bray's solution.

Dissolved organics, including TFM and possible derivatives, were recovered by passing the incubation media over a 2 × 12-cm bed of Amberlite XAD-2. The retained organics were eluted with redistilled methanol and chromatographed on silica gel plates in two solvent systems (benzene:diethyl ether:acetic acid; 10:5:0.1 and benzene:acetone:ammonium hydroxide; 15:5:0.1) against authentic TFM and RTFM standards. The plates were divided into 1-cm segments from origin to front which were scraped into liquid scintillation vials for counting to determine which spots contained ^{14}C

TFM was visualized on the plates by exposure to ammonia vapors, and RTFM by spraying with 2% *p*-dimethylaminobenzaldehyde in ethanolic 0.1 N HCl.

Verification of the materials was done by gas chromatography according to the following procedure. An aliquot of the XAD-2 methanol eluate was evaporated to dryness and redissolved in 0.1 M phosphate buffer, *p*H 6.0. This solution was extracted twice with 1 vol of diethyl ether which was subsequently dried with sodium sulfate and evaporated to 1 ml. Acetic anhydride was added in the ratio of 0.2 ml/ml of ether sample and the samples were held at 50 C for 30 min prior to injection. Authentic TFM and RTFM standards were prepared in the same manner.

TFM, obtained from the Lamprey Research Station, U.S. Department of the Interior, Hammond Bay, Michigan, was purified as previously described (Lech 1971). ^{14}C-TFM was a gift from the U.S. Department of the Interior, Fish Control Laboratory, LaCrosse, Wisconsin. RTFM was prepared from TFM by catalytic reduction as previously described (Lech 1973). Thin layer chromatography plates (silica gel) were obtained from Brinkman Company, Westburg, New York, and the gas chromatographic column from Applied Science Laboratories, State College, Pennsylvania. All other chemicals and solvents were of reagent grade and were purchased locally.

Results

All three experiments indicated that under aerobic conditions TFM remained essentially unaltered. In the first experiment, with aerobic conditions, there was no significant decrease in optical density at 395 nm in either of the TFM containing bottles for a 2.5-month period (Fig. 1B). Similarly, there was no change in the radioactivity of the supernatant water (Fig. 1A).

Thin-layer chromatography of the XAD-2 methanol fraction obtained from these flasks also indicated that there had been no alteration of the TFM molecule. Essentially all of the ^{14}C was retained by the XAD-2 resin and the only labelled organic compound in the methanol eluate had R_f values identical to those of TFM when chromatographed on silica gel plates in two solvent systems.

The aerobic flasks of the second experiment corroborated this finding. At saturated oxygen levels there was no significant decrease in optical density at 395 nm during the 2.5-month incubation (Fig. 2A–D). At the end of the experimental period 1 liter from each flask was passed through an XAD-2 column. Silica gel TLC of the concentrated methanol

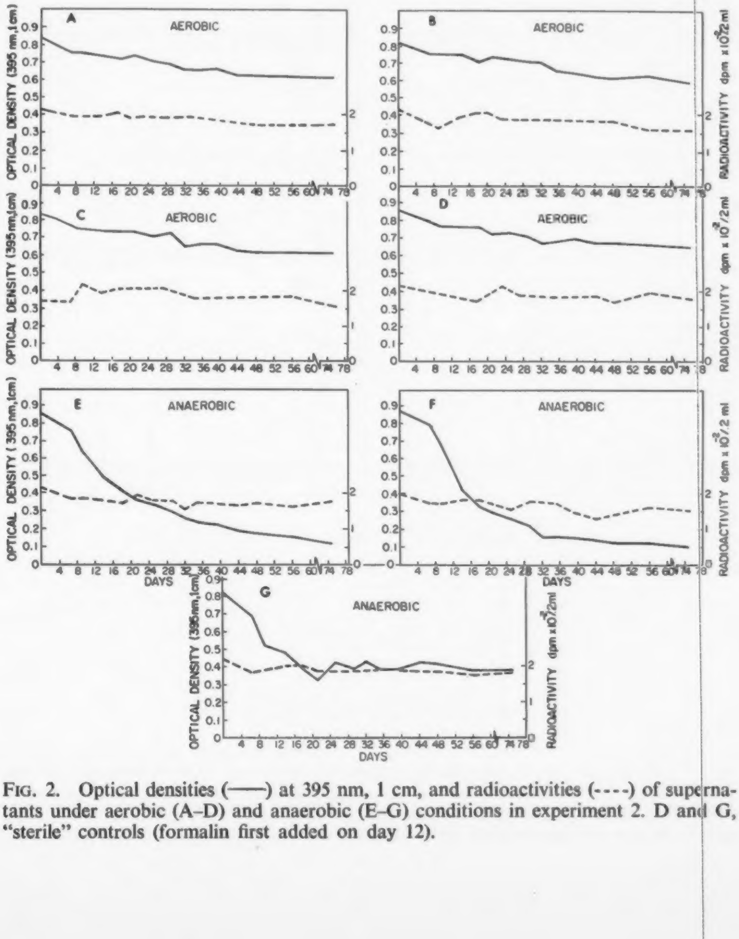

FIG. 2. Optical densities (——) at 395 nm, 1 cm, and radioactivities (----) of supernatants under aerobic (A–D) and anaerobic (E–G) conditions in experiment 2. D and G, "sterile" controls (formalin first added on day 12).

eluate showed that nearly all of the radioactivity in these flasks was associated with the TFM spot (Fig. 3A–D).

Gas-chromatographic analysis of the ether extracts of the XAD-2 methanol eluate confirmed the results obtained by thin-layer chromatography. Only unchanged TFM was found in the flasks which were incubated under areobic conditions (Fig. 4A–D).

Aerobic incubation of TFM in the presence and absence of 25 g/liter phenol in the third experiment (Fig. 5A, B) showed a progressive fall in both the optical density at 395 nm and the level of supernatant radioactivity. This effect was not seen with the sediments used in the aerobic systems in experiments 1 and 2. Since there were no metabolites found either in the supernatant or in the sediments and the fall in radioactivity paralleled the decrease in optical density at 395 nm, this disappearance may be attributed to binding of TFM to the sediment. Further evidence for this is the observation that 25 g/liter phenol prevented both the fall in super-

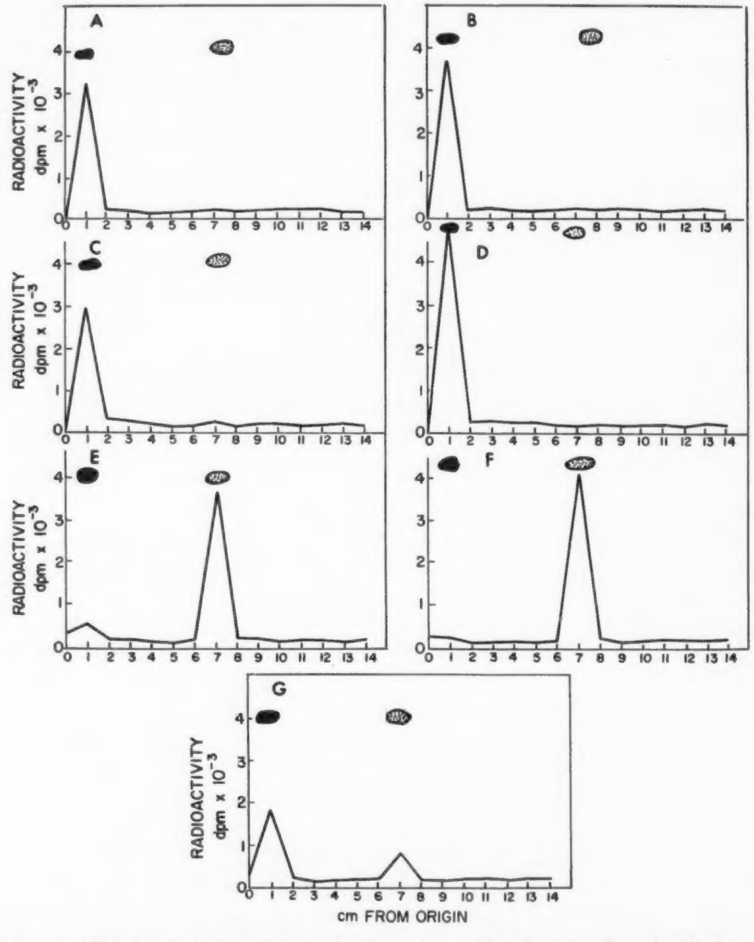

FIG. 3. Thin-layer chromatograms of supernatant methanol extract from incubations in experiment 2. Chromatographed on silica gel in benzene:acetone:ammonium hydroxide, 15:5:0.1. A–D, aerobic; E–G, anaerobic; D and G, "sterile" controls; ——, radioactivity on chromatograms; dark spot, authentic TFM; stippled spot, authentic RTFM.

natant optical density and radioactivity (Fig. 5B). This effect of phenol has been previously observed by Kempe (1973) and was thought to be due to inhibition of TFM binding to sediments.

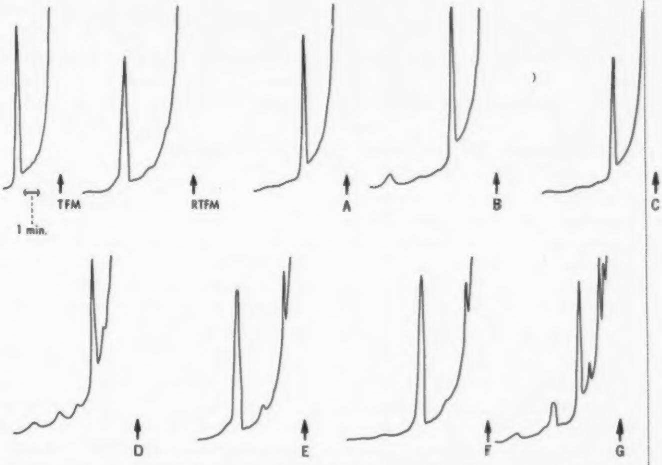

FIG. 4. Gas chromatograms of supernatant methanol extract from incubations in experiment 2, and authentic TFM and RTFM standards. A–D, aerobic; E–G, anaerobic; D and G, "sterile" controls. Retention time for acetylated TFM, 2.5 min; for acetylated RTFM, 4.1 min. Arrows denote injection points.

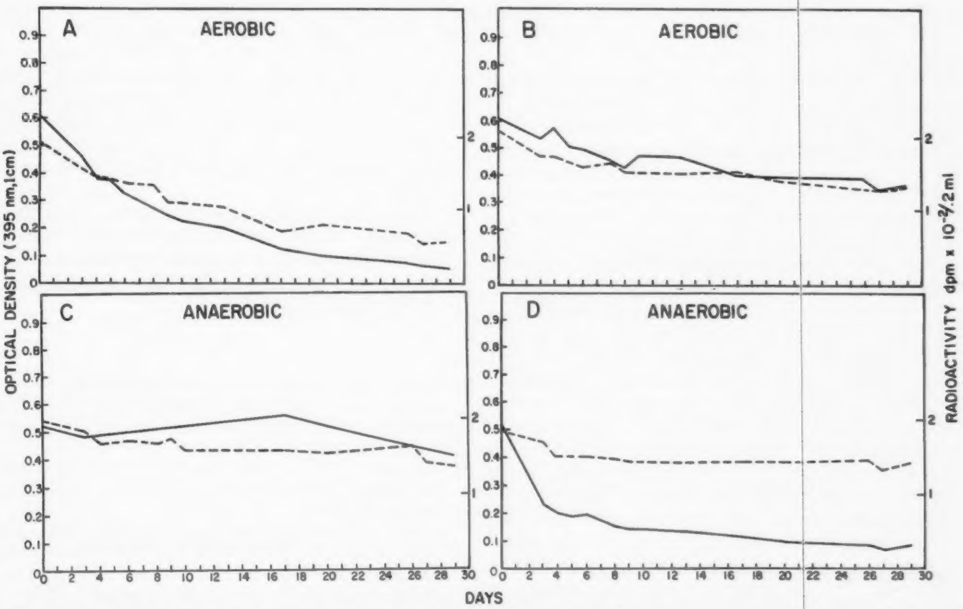

FIG. 5. Optical densities (——) and radioactivities (----) of supernatants in incubations from experiment 3. A and B, aerobic; C and D, anaerobic. Phenol (25 ppt) added to systems B and C at day 0.

Under reduced oxygen tensions all experimental evidence indicated that TFM was reduced to RTFM. In the first experiment after the carboys were enriched with organics, vigorous bacterial growth depleted oxygen within 48 hr. Five days after enrichment the optical density in the carboy with 1200 g of sediment had begun to decrease. Three days later it had reached almost zero (Fig. 1B). Optical density in the bottle with only 50 g of sediment did not approach zero until 20 days following enrichment. However, radioactivity levels of the supernatant in both bottles remained constant during this time (Fig. 1A), indicating that the decrease in optical density at 395 nm was not the result of sorption of TFM onto sediment surfaces.

The organics retained by XAD-2 resin from the first carboy were chromatographed soon after the loss of color. Again, the column removed all of the ^{14}C label. However, this time the ^{14}C-labelled material had an R_f value identical to that of RTFM and this spot was also positive when sprayed for aromatic amines. Labelled TFM was no longer present.

Bacterial activity in the second bottle was allowed to continue for 2 months after the optical density of the solution had reached zero. TLC analysis showed that most of the label still remained in RTFM.

Oxygen levels in the anaerobic flasks of the second experiment varied from 0.0 to 0.4 mg/liter. Under these conditions optical density at 395 nm rapidly declined from 0.8 to 0.1 OD units (Fig. 2E, F). Since the anaerobic "sterile" control also began to show decreases in optical density during the first 10 days, additions of formalin were made to inhibit possible bacterial growth. After several additions of the preservative during a week the optical density levelled off at about 0.4 OD units and remained at this level for the duration of the study (Fig. 2G).

Silica gel TLC of the methanol eluate from these low oxygen regime flasks showed that most of the ^{14}C was located in the RTFM spot with some radioactivity remaining in the TFM area and on the origin (Fig. 3E, F). The radioactivity on the origin may be associated with another degradation product of TFM. Unfortunately, the quantities obtained were too small to be isolated and identified.

The anaerobic "sterile" control to which formalin was added showed the carbon label to be distributed between TFM and RTFM. Again a small amount of radioactivity remained on the origin (Fig. 3G).

Gas chromatography confirmed that the major material found in the anaerobic flasks was RTFM (Fig. 4E, F). The "sterile" anaerobic system to which formalin had been added on day 12 contained both TFM and RTFM (Fig. 4G).

In the anaerobic system without phenol in experiment 3 (Fig. 5D) there was a rapid decrease in the optical density at 395 nm, without a parallel decrease in radioactivity. As in the previous experiments, after 29 days all of the radioactivity was identified as RTFM. (Fig. 5C) Inclusion of 25 g/liter phenol prevented both the decrease in optical density at 395 nm and the fall in radioactivity (Fig. 5C). Only unchanged TFM was found under these latter conditions.

Discussion

The results obtained in the above experiments suggest that the loss of optical density at 395 nm observed by Kempe (1973) was due to the reduction of TFM to 3-trifluoromethyl-4-aminophenol under anaerobic conditions.

Experiments 2 and 3 suggest that the reduction of TFM is primarily due to microbial activity. Although the autoclaved sediments maintained under anaerobic conditions in the second experiment showed significant reduction of TFM initially, this is thought to have been the result of subsequent bacterial contamination during sampling. After formalin (3% v/v final concn) was added to check microbial growth, the conversion of TFM to RTFM ceased. The anaerobic series of the third experiment also supports this idea because phenol (25 g/liter), a known bactericidal agent, inhibited reduction of TFM.

The small amount of radioactivity remaining at the origin of the thin-layer chromatograms of the anaerobic flask extracts from the second experiment was the only sign of other possible degradation products of TFM. No evidence for breakdown of TFM under aerobic conditions has yet been reported.

Caution should be exercised, however, in applying these results to the environment in which TFM is used. Additional work is needed to determine the influence of other factors, such as light, on stability of TFM under natural conditions.

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Behavior of Adult American Shad (*Alosa sapidissima*) Homing to the Connecticut River from Long Island Sound

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DODSON, J. J., AND W. C. LEGGETT. 1973. Behavior of adult American shad (*Alosa sapidissima*) homing to the Connecticut River from Long Island Sound. J. Fish. Res. Board Can. 30: 1847–1860.

The migratory behavior of American shad (*Alosa sapidissima*) approaching their natal river during the final saltwater stage of the spawning migration was studied using ultrasonic tracking and conventional tagging procedures. Initial displacement of most sonic-tagged shad released without displacement adjacent to and 10 km west of the Connecticut River was not in the direction of the home river. These fish, however, homed successfully to the Connecticut River as did dart-tagged shad released in the same areas.

Shad exhibited two major behavior patterns; countercurrent orientation in response to the reversing tidal current and adjustment of swimming speed to changes in tidal velocity. Countercurrent orientation was equally significant during daylight and darkness, whereas the adjustment of swimming speeds to tidal current velocity was more significant during daylight than darkness.

Shad tracked to the west exhibited a westerly bias inherent in the basic open water behavior patterns. Shad exhibited a greater degree of directed movement when oriented against the ebb tide and adjusted their swimming speeds to exceed the ebb tide velocity and to approximately equal the flood tide velocity. Shad tracked to the east exhibited the same major behavior patterns but with the opposite directional bias.

A hypothesis is presented suggesting that the location of the home river is achieved by means of a nonrandom search. Environmental clues indicative of the Connecticut River act to establish a preferred direction of displacement while the actual unidirectional displacement is achieved by reference to the rate and direction of tidal currents.

DODSON, J. J., AND W. C. LEGGETT. 1973. Behavior of adult American shad (*Alosa sapidissima*) homing to the Connecticut River from Long Island Sound. J. Fish. Res. Board Can. 30: 1847–1860.

Les auteurs ont étudié le comportement d'aloses savoureuses (*Alosa sapidissima*) au moment où elles s'approchent de leur rivière natale dans la phase finale en mer de leur migration de fraie. Ils ont fait appel au dépistage aux ultrasons et aux marquages ordinaires.

Le déplacement initial de la majorité des aloses munies de marques sonores et relâchées à l'endroit de capture à 10 km à l'ouest de la rivière Connecticut ne s'est pas produit en direction de la rivière natale. Ces poissons ont cependant réussi à revenir à la rivière Connecticut, tout comme des aloses marquées avec des dards et relâchées aux mêmes endroits.

Les aloses manifestent deux types principaux de comportement: une orientation à contre-courant en réponse aux changements de direction des courants de marée et réglage de la vitesse de nage en fonction des changements de vitesse de ce courant. Cette orientation à contre-courant se produit à la lumière du jour aussi bien qu'à l'obscurité, alors que le réglage de la vitesse natatoire par rapport à la vitesse du courant de marée est plus prononcé à la lumière du jour qu'à l'obscurité.

Les aloses suivies vers l'ouest montrent un biais marqué vers l'ouest qui est inhérent au comportement de base en pleine eau. Les aloses ont un mouvement dirigé de façon plus précise lorsqu'elles sont orientées contre le reflux et elles règlent leur nage à une vitesse dépassant celle du reflux et à peu près égale à celle du flux. Les aloses suivies à l'est se comportent généralement de la même façon mais avec biais en direction opposée.

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AMERICAN shad (*Alosa sapidissima*) undertake long distance oceanic migrations (Talbot and Sykes 1958; Sykes and Talbot 1958) and return to their home rivers to spawn (Walburg and Nichols 1967). Leggett and Whitney (1972) demonstrated that the timing and pattern of these extensive migrations are regulated by adherence to specific water temperatures in the range of 13–18 C. Seasonal changes in the 13–18 C isotherm along the Atlantic coast coincides with the southward migration of shad in the winter and the northward migration in the early spring and summer. The northward migration brings shad to the vicinity of their home rivers at times when river conditions are approaching the optimum for spawning.

Tagging studies also indicate that shad return to their natal streams to spawn (Truitt 1940; Hollis 1948; Vladykov 1950; Talbot and Sykes 1958; Nichols 1961). Leggett and Whitney (1972) reported that between 1965 and 1969, 18,374 mature shad were marked and released in the lower Connecticut River. Over 300 shad were recovered in the Connecticut River one year or more after tagging while none were recovered in other rivers.

Although the overall timing, route, and control mechanism of the shad migration is now established, the means by which shad locate and recognize specific natal rivers was heretofore unknown. This paper describes the behavior of adult shad, native to the Connecticut River, during their approach to the river from Long Island Sound and comments on possible environmental factors controlling the behavior.

Materials and Methods

The orientation and migratory behavior of shad was investigated by a combination of conventional tagging and ultrasonic tracking techniques. Conventional tags were used to assess the frequency of return of shad to the Connecticut River and the time taken to home. Ultrasonic tracking techniques (Trefethen 1956; Stasko, 1971) were used to analyze the minute to minute behavior of shad in response to various environmental variables.

ULTRASONIC TRACKING PROCEDURES

A total of 43 adult American shad fitted with sonic transmitters were tracked in Long Island Sound (Fig. 1) during April, May, and June of 1970 and 1971. The tags (Smith-Root model 69-B) had a frequency of 70 KHZ, a range of 30–300 m, depending on water conditions, and an effective life of 15 days. They were housed in polystyrene cylinders 6.4 cm long and 1.3 cm in diameter; approximate weight was 14.5 g in air. The receiving unit consisted of a portable battery operated receiver (Smith-Root model TA-60) tunable in the range 60–180 KHZ coupled to a hydrophone having a peak frequency of 70 KHZ and a cone of reception of approximately 15°. Swimming depth of tracked fish was unknown.

All fish were captured with 14-cm (stretch measure) monofilament gillnets and removed from the net immediately upon capture, as indicated by the movement of the headrope floats. If unharmed, a sonic tag was inserted into the stomach via the mouth and each fish was gently returned to the water.

Tagging was accomplished in two areas of Long Island Sound; (a) Westbrook, Connecticut (72°28′, 41°16′) and, (b) the west side of the Saybrook Point breakwater (72°20′40″, 41°15′50″) (Fig. 1). A third fishing area, located 10 km east of the Connecticut River, was fished in 1971. No shad were ever captured in this area.

Movements of these tagged fish were monitored by immediate and continuous tracking from a 6.4-m boat which was maintained behind and in line with the tagged fish. This was possible due to the directivity of the hydrophone which was manually rotated in the water. The distance between the fish and the boat was estimated by changes in incoming signal strength. The position of the fish was obtained at least every 30 min by triangulation. Whenever possible, cloud cover, wind strength and direction, wave condition, tidal condition, depth, temperature and salinity (measured at 2-m increments), and fish swim-speed (expressed as boat speed through the water) were recorded coincident with fish position. Temperature and salinity were measured with a Hydrolab TC-2 conductivity meter. Boat speed through the water was measured with a Gurly flowmeter.

Automatic shore monitors were utilized to detect the upriver passage of sonic-tagged shad which had previously been tracked at sea. In 1970, five shore-based monitors were located along the Connecticut River at points 7, 13, 31, 33, and 34 km upstream of the river's mouth. In 1971, two shore-based monitors were located 7 km upstream of the river's mouth. Each monitor contained two receivers which were connected to two hydrophones placed on the river bottom. The incoming signals to each receiver were recorded on separate tracks of a magnetic tape recording system. A time signal was automatically recorded on a third track every 6 min. The time of fish passage was obtained by adding the time marks in tenths of hours to the starting time of the tape. Individual fish were identified by the tag pulse, which was determined for each tag and recorded for each fish at the time of tagging.

The displacement of shad in Long Island Sound resulted from two factors: the speed and direction of tidal currents, and the heading and swimming speed of the fish. Data on tidal rate and direction were available from our records, and from tidal tables and charts for Long Island Sound. These data were combined and used together with observations of fish displacement over time to calculate fish bearing and swimming speed using triangulation and vector velocity techniques. Swimming speeds so calculated are hereafter referred to as "calculated swim-speeds." This represents the minimum speed at which a given fish must swim to travel a straight line between two points in a given increment of time. As such, it tends to underestimate the actual swimming speed, since straight line courses were seldom followed.

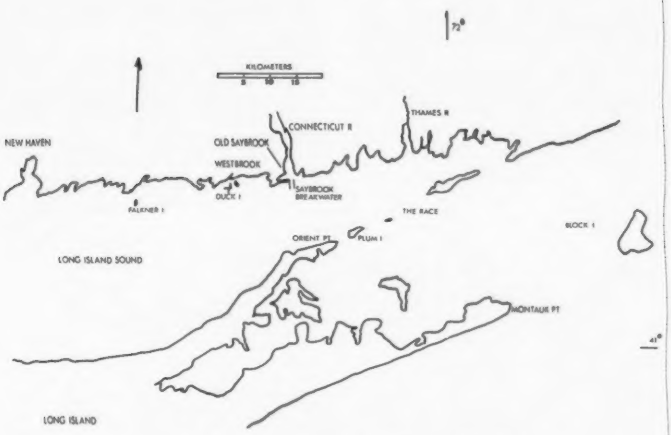

FIG. 1. Location map of Long Island Sound.

Current velocity values presented in the tidal charts and tables for Long Island Sound were obtained from measurements made to a maximum depth of 6 m (U.S. Coast and Geodetic Survey). As the depth of tracked shad could not be measured, a knowledge of differences in current velocity throughout the water column was necessary to assess the accuracy of swimming speed estimates. Riley (1956) reported that at midtide, when current velocities are maximum, the flood (westerly flowing) tide velocity remains relatively constant throughout the water column, whereas the ebb (easterly flowing) tide velocity is greater on the surface than on the bottom (30 m). Thus, the absolute magnitudes of swimming speeds calculated during ebb tide conditions may be overestimated if the fish were swimming deeper than 6 m. As the majority of shad were tracked within the 9-m contour line, we do not feel that this is a major source of error. Nevertheless, to avoid incorporating this possible source of error, swimming speeds calculated under each tidal condition were not directly compared. Rather, swimming speeds were examined relative to tidal velocity.

Swimming speeds were also estimated by recording the average speed of the boat through the water as the fish proceeded from one point to the next along the track. These estimates were biased as it was impossible to accurately integrate the observations over the entire ½-hr period. They therefore tend to represent the swim-speed of the fish at the times of positioning and data collection rather than an average value between two points. These swim-speeds are hereafter referred to as "observed swim-speeds."

CONVENTIONAL TAGGING PROCEDURES

Coincident with the sonic tracking experiments, a total of 330 shad were externally marked with nylon dart-type tags in 1970 and 1971 and released in the same areas as the sonic tagged shad. The numbers of fish recaptured in the Connecticut River by commercial and sport fishermen were analyzed for the frequency of return.

Analysis of dart-tag recoveries in the Connecticut River provided estimates of mean homing times from Westbrook and Saybrook. Dart-tagged shad were captured by sport and commercial fishermen from Old Saybrook at the river's mouth to Enfield Dam which is located 137 km upstream. Mean homing times were calculated by subtracting the time spent in the river from the total time elapsed between the tagging and subsequent recapture of shad. The time spent in the river was based on an estimated upstream migration rate of 6.1 km/day (Glebe and Leggett 1973).

Results

PATHS OF MIGRATION AND HOMING ABILITY

Forty-three sonic-tagged shad were continuously tracked in Long Island Sound during 1970 and 1971 for a total tracking time of 613 hr. No shad were tracked into the Connecticut River. Furthermore, 40 of 43 shad exhibited a westerly displacement away from the Connecticut River (Fig. 2, 3). However, 7 (39.8%) of 18 dart-tagged shad released at Westbrook in 1970 were recovered in the Connecticut River by commercial fishermen during the same year. This recovery did not differ significantly from the recovery of 879 (21.8%) of 4072 dart-tagged shad released in the lower Connecticut River and subsequently recovered in the river during 1970 (Leggett 1970) (chi-square = 1.78, df = 1, $P > 0.5$). Similarly, 58 (18.6%) of 312 dart-tagged shad released in Long Island Sound in 1971 were recovered in the Connecticut River. This recovery did not differ significantly from the recovery of 864 (20.8%) of 4147 dart-tagged shad released in the lower Connecticut River and subsequently recovered in the river in 1971 (Leggett 1971) (chi-square = .59, df = 1, $P > .05$). These findings indicated that shad tagged at Westbrook and Saybrook were homing to the Connecticut River.

In 1970, 4 sonic tags were recovered by commercial and sport fishermen in the Connecticut River. The automatic shore-based monitors were plagued

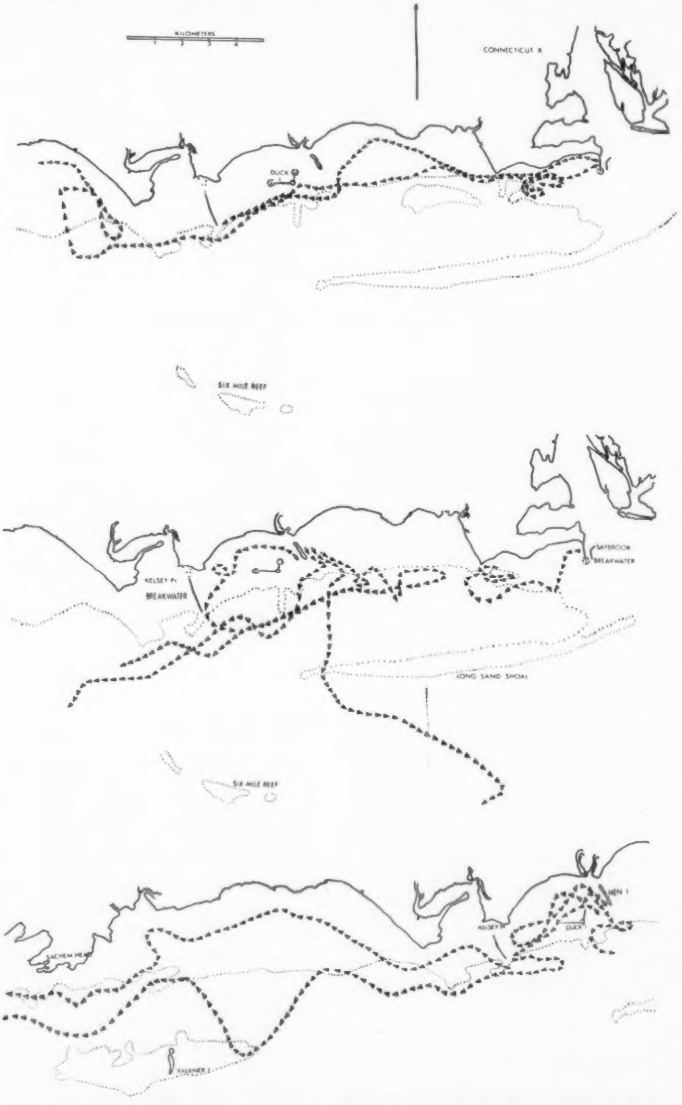
KILOMETERS
1
2
3
4
CONNECTICUT R
DUCK
SIX MILE REEF
KELSEY Pt
BREAKWATER
SAYBROOK
BREAKWATER
LONG SAND SHOAL
SIX MILE REEF
SACHEM HEAD
KELSEY Pt
DUCK
MEN I
FALKNER I

FIG. 2. Migration routes of 10 shad tracked in 1970. These shad were selected as being characteristic of the other tracks. Solid line represents shoreline, dotted *line represents 9 m contour line, arrows represent direction of fish displacement.*

by repeated malfunction in spite of daily inspection and testing. Interrogation of the magnetic tapes revealed 11 sonic tags recorded in 1970 and five in 1971. Tape advance malfunctions and time gaps in the monitoring system eliminated the possibility of identifying individual tags or their time of passage. However, it was possible to discriminate between different signals and thus to determine the minimum number of sonic-tagged shad entering the river.

Daily inspection of the monitors involved checking the tape advance mechanism, assessing the sensitivity of the hydrophones, and recording a short message on the tape for reference at the time of interroga-

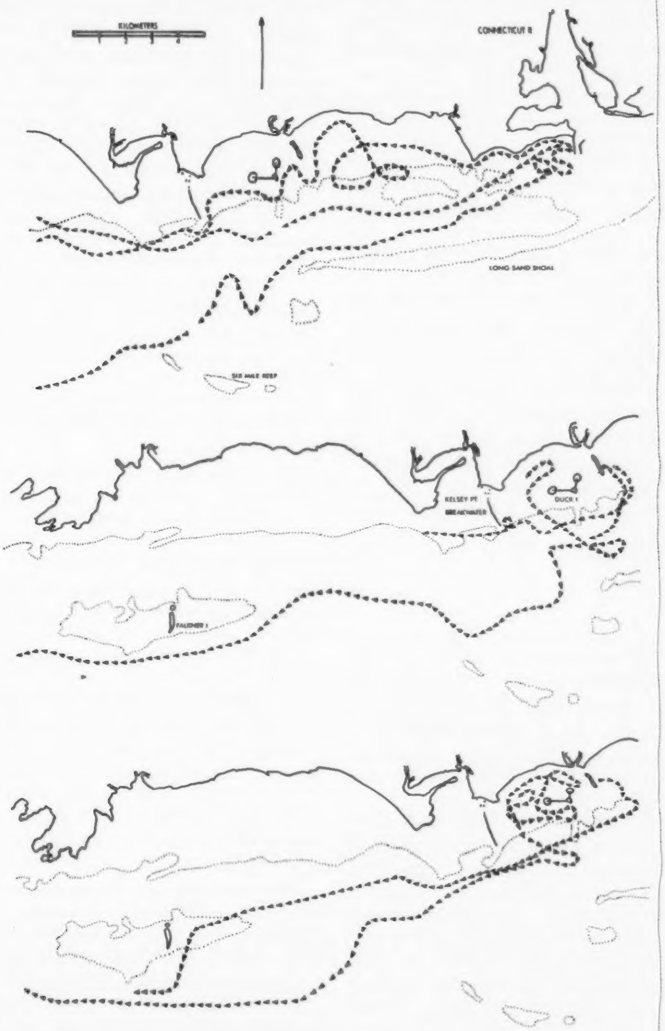

FIG. 3. Migration routes of eight shad tracked in 1971. These shad were selected as being characteristic of the other tracks. Solid line represents shoreline, dotted line represents 9 m contour line, arrows represent direction of fish displacement.

tion. Over 50% of these messages were not detected during tape interrogation indicating that the monitors also suffered malfunctions of the recording system. It was therefore impossible to estimate the monitors' efficiency of tag detection. The frequency of detection (37% or 16 of 43 sonic tags released) is believed to be compatible with the detection efficiency of the shore monitors and, therefore, indicative of successful homing to the Connecticut River.

The frequency of recovery of dart-tagged shad released at Westbrook in 1971 (23 of 106) was not significantly different from the frequency of recovery of dart-tagged shad released at Saybrook in 1971 (35 of 206) (chi-square = .69, df = 1, $P>.1$). The mean homing time for dart-tagged shad released at Westbrook in 1970 and 1971 was 7.9 days (SD = 6.7, $n = 25$), and for dart-tagged shad released at Saybrook was 5.2 days (SD = 4.9, $n = 20$).

These long mean homing times for fish migrating over relatively short distances indicated that the homing migration in Long Island Sound was extensive and not direct. This conclusion was supported by observations of the paths of shad tracked in 1970 and 1971 (Fig. 2 and 3).

In 1970, three shad were tracked east from Westbrook towards the Connecticut River. One shad turned west before arriving at the river, whereas the remaining two reached the river and remained in the vicinity of its mouth for approximately 2 hr before leaving. One was tracked west beyond Westbrook while the second migrated southeast (Fig. 4). No fish were tracked east in 1971.

RESPONSE TO TIDE

That portion of the data associated with open water migration, i.e. not associated with fish movements about breakwaters, islands, and similar obstructions, was extracted from the main body of data and analyzed. The 1st hr of individual tracks was excluded from the analysis to avoid incorporating nonsense behavior arising from possible temporary disorientation due to handling.

The data included 442 observations on 16 shad tracked in 1970 and 680 observations on 20 shad tracked in 1971. Seven shad were excluded from the analysis as they were either lost shortly after release or were tracked in areas where tidal current readings could not be obtained. Individual shad were analyzed if the shad were tracked through at least one tidal cycle. Twelve shad tracked in 1970 and 13 shad tracked in 1971 were analyzed individually.

Fish bearing — Long Island Sound is subjected to a reversing tide every 6 hr. The incoming (flood) tide flows approximately west and the outgoing (ebb) tide flows approximately east.

In 1970 and 1971, shad exhibited a strong tendency to orient into the tidal current.

1970, $r = -.479$, $n = 388$, $P<.001$, grouped data
1971, $r = -.502$, $n = 432$, $P<.001$, grouped data

This countercurrent orientation was equally significant during daylight and darkness. However, the precision of the countercurrent orientation differed depending on the direction of the tidal current. The countercurrent orientation of 9 of 12 shad tracked in 1970 was more precise when bearing west against the ebb tide (Fig. 5A). The remaining three shad exhibited greater precision when oriented to the east. Of these three, two (no. 07 and 08) initially pursued an easterly course towards the Connecticut River. Four shad, although exhibiting precise countercurrent orientation when bearing west, exhibited concurrent behavior under the influence of the westerly flowing tide. In 1971, the countercurrent orientation of 12 of 13 shad was more precise when bearing west into the ebb tide (Fig. 5B). The remaining shad exhibited similar precision during both tides. Four shad tracked in 1971 exhibited concurrent orientation under the influence of the flood tide. Three other shad approached this situation.

The differences in precision of countercurrent orientation between the two tidal conditions was also evident in the magnitude of angular changes in bearing exhibited by shad. Turning angles were smallest when shad were bearing west against the ebb tide. In 1970, the frequency of angular changes greater than 45° exhibited by shad tracked during ebb tide conditions was 33.3% (65 of 195 observations). The corresponding frequency during flood tide conditions was 57.3% (82 of 143 observations). This difference is statistically significant (chi-square = 7.48, $P<.01$). Similarly in 1971, the frequency of angular changes greater than 45° observed during ebb tide conditions was 24.7% (46 of 186 observations) and during flood tide conditions was 52.8% (104 of 197 observations). Again this difference is statistically significant (chi-square = 14.05, df = 1, $P<.01$).

Nineteen of 25 fish tracked in 1970 and 1971 and analyzed individually exhibited smaller turning angles when bearing west during ebb tide conditions (Fig. 6A–F). Six shad exhibited smaller turning angles when bearing east during flood tide conditions (Fig. 6G–I). Of these shad, three were initially tracked east to the mouth of the Connecticut River.

Angular changes in bearing exhibited by shad were not dependent on the time of day or the availability of celestial clues. There was no difference in the frequency of large turning angles (>45°) observed during day and night tracks (Table 1A). Similarly, the frequency of large turning angles did not differ between clear and overcast daytime

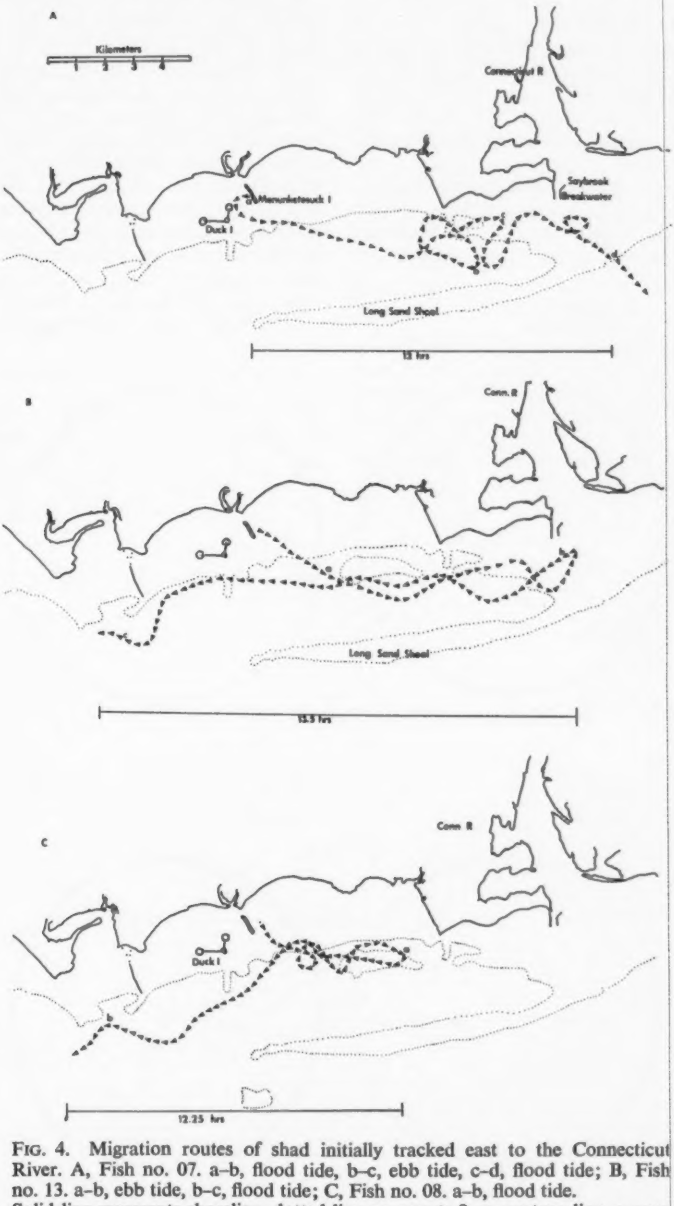
A
Kilometers
1
2
3
4
Connecticut R
Saybrook
Breakwater
Menunketesuck I
Duck I
Long Sand Shoal
12 hrs
B
Conn. R
Long Sand Shoal
15.5 hrs
C
Conn R
Duck I
12.25 hrs

FIG. 4. Migration routes of shad initially tracked east to the Connecticut River. A, Fish no. 07. a–b, flood tide, b–c, ebb tide, c–d, flood tide; B, Fish no. 13. a–b, ebb tide, b–c, flood tide; C, Fish no. 08. a–b, flood tide.
Solid line represents shoreline, dotted line represents 9 m contour line, arrows represent direction of fish displacement.

skies (Table 1B) or between clear and overcast night skies (Table 1C).

Fish swimming speed — The mean calculated swim-speed of shad tracked in 1970 was 75.3 cm/sec (SD = 42.7) and in 1971 was 71.9 cm/sec (SD = 36.6). The frequency distribution of calculated swim-speeds for 1970 and 1971 are presented in Fig. 7. No diel periodicity was evident in shad swimming speeds.

A strong positive correlation was revealed between swim-speed and tidal current velocity in both 1970 and 1971. The correlation was more significant during daylight than darkness (Table 2). Analysis of 25 individual shad revealed that eight shad exhibited a significant adjustment of swim-speed to tidal velocity, five shad approached significance and 20 shad exhibited a positive relationship between swimming speeds and tidal current velocity.

The adjustment of swim-speed to tidal velocity differed according to tidal condition. Linear regression analysis of swim-speed/tidal velocity data revealed that in 1970, under ebb tide conditions, $b = 0.64$, and under flood tide conditions, $b = 0.25$. Thus, increment increases in ebb tide velocity produced greater increases in swim-speed than did similar increases in the flood tide velocity. In 1971, linear regression analysis revealed that, under ebb

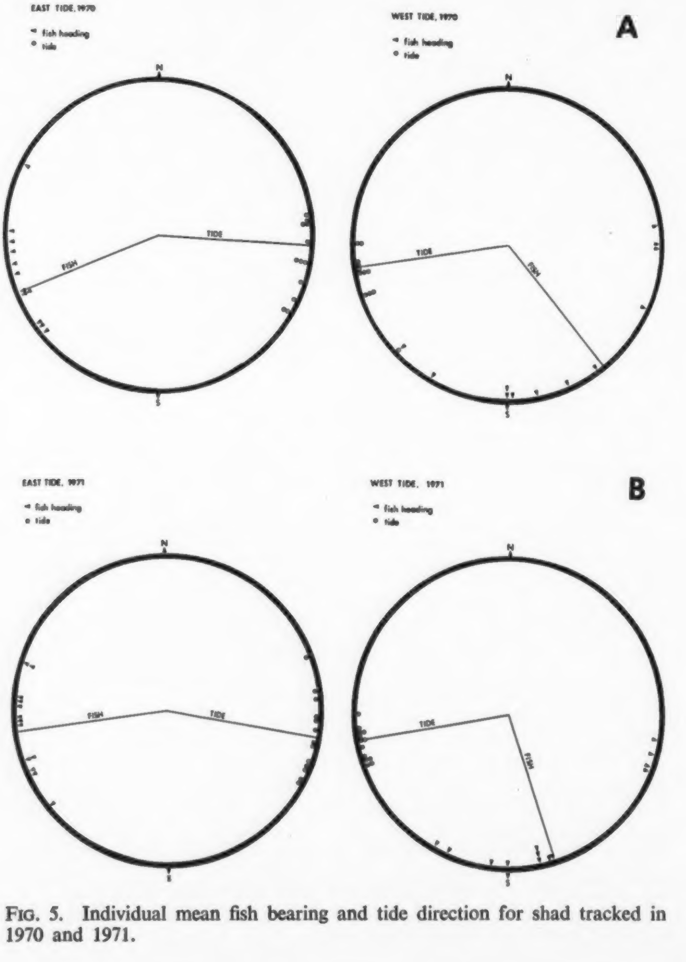

FIG. 5. Individual mean fish bearing and tide direction for shad tracked in 1970 and 1971.

tide conditions, $b = 0.45$. The regression was not significant for flood tide conditions.

In 1970 and 1971, shad swam west at a rate significantly greater than the ebb tide velocity (*t*-test, $P < .001$, grouped data) but under flood tide conditions swam at a rate approximately equal to the tidal velocity (Table 3). This relationship was observed during daylight and darkness (Table 4).

A sign test (Siegal 1956) applied to the swim-speed/tidal velocity data for individual shad tracked in 1970 and 1971 revealed that the majority of individual shad (22 of 25) swam at speeds in excess of the current velocity during ebb tide conditions ($P < .01$). Under flood tide conditions, the proportion of shad swimming at speeds in excess of tidal velocity (11 of 25) did not exceed the proportion swimming at speeds less than tidal velocity ($P < .4$).

RESPONSE TO TEMPERATURE AND SALINITY

Decreased surface salinity and increased surface water temperatures in Long Island Sound are indicative of the presence of Connecticut River water. The results of a correlation analysis carried out on observed swimming speeds, surface salinity, and surface temperature revealed that in 1970 and 1971, 13 of 17 shad exhibited a negative relationship between observed swimming speed and surface salinity. This proportion was significantly greater than the proportion of shad exhibiting a positive relationship (binomial test (Siegal 1956) $P = .025$).

In 1970 and 1971, 11 of 20 shad exhibited a positive relationship between observed swim-speed and surface temperature. This proportion was not significantly different from the proportion of shad exhibiting a negative relationship (binomial test, (Siegal 1956) $P = .412$).

Discussion

The observed westerly displacement of 40 of 43 shad captured west of the Connecticut River suggested that these fish entered Long Island Sound from the east and migrated beyond their home river. Stevenson (1899) stated that the majority of shad entered Long Island Sound through the Race (Fig. 1). He further stated that most of these shad migrat-

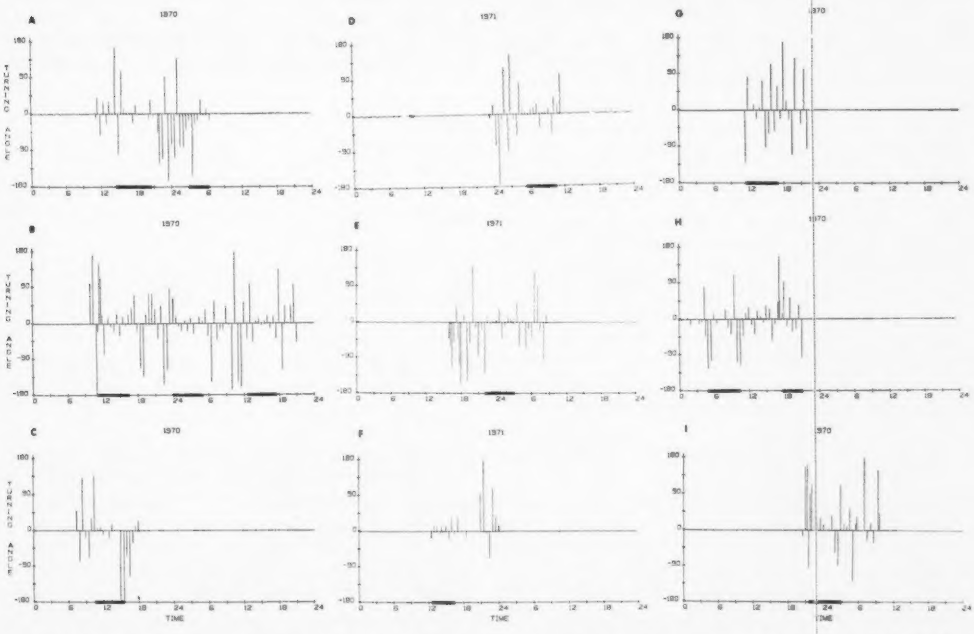

FIG. 6. Turning angles of six shad (A–F) initially tracked west in 1970 and 1971 and three shad (G–I) initially tracked east in 1970. A, Fish no. 02, 1970; B, Fish no. 06, 1970; C, Fish no. 03, 1970; D, Fish no. 12, 1971; E, Fish no. 08, 1971; F, Fish no. 13, 1971; G, Fish no. 08, 1970; H, Fish no. 07, 1970; I, Fish no. 13, 1970. Solid bar on the time axis represents duration of ebb tide (not including slack tide).

ed up the Connecticut River, but a large number proceeded westward to spawn in the Housatonic River and other smaller streams along the Connecticut shore. No shad were taken in the Housatonic River in 1960 and only occasional shad have been caught there since that time; dams and pollution have virtually eliminated this and other runs in rivers and streams located west of the Connecticut River (Walburg and Nichols 1967). In the light of this evidence and the recovery of dart- and sonic-tagged shad in the Connecticut River, it is concluded that shad caught west of the river were Connecticut River shad which had migrated beyond their natal river.

TABLE 1. Frequency of large turning angles exhibited by American shad (*Alosa sapidissima*) during (A) day and night, (B) clear and cloudy days, and (C) clear and cloudy nights in Long Island Sound.

	Year	*n*	%>45°	*n*	%>45°	Chi^2	*P*
			Day		*Night*		
(A)	1970	236	43.2	135	45.1	.05	>.05
	1971	260	36.2	149	42.3	.66	>.05
			Clear days		*Cloudy days*		
(B)	1970	124	45.2	112	41.1	.159	>.05
	1971	135	38.5	125	33.6	.319	>.05
			Clear nights		*Cloudy nights*		
(C)	1970	61	40.9	74	48.6	.301	>.05
	1971	91	43.9	58	39.7	.110	>.05

Historically, the most successful shad fishery in Connecticut was located west of the Connecticut River along the north shore of Long Island Sound. Three-pound nets located here caught more shad than all others combined (Walburg and Nichols 1967). In contrast, few shad have ever been caught east of the Connecticut River. A shad population native to the Thames River, located to the east of the Connecticut River (Fig. 1), was eliminated by 1896 (Stevenson 1899). Only a few shad have been caught in the Thames River since that time (Walburg and Nichols 1967). This evidence and our own failure to capture shad east of the Connecticut River leads to the conclusion that shad, native to the Connecticut River entering Long Island Sound via the Race, do not approach the northern shoreline at points east of the Connecticut River. Rather, the main body of Connecticut River shad appears to concentrate along the north shore of Long Island

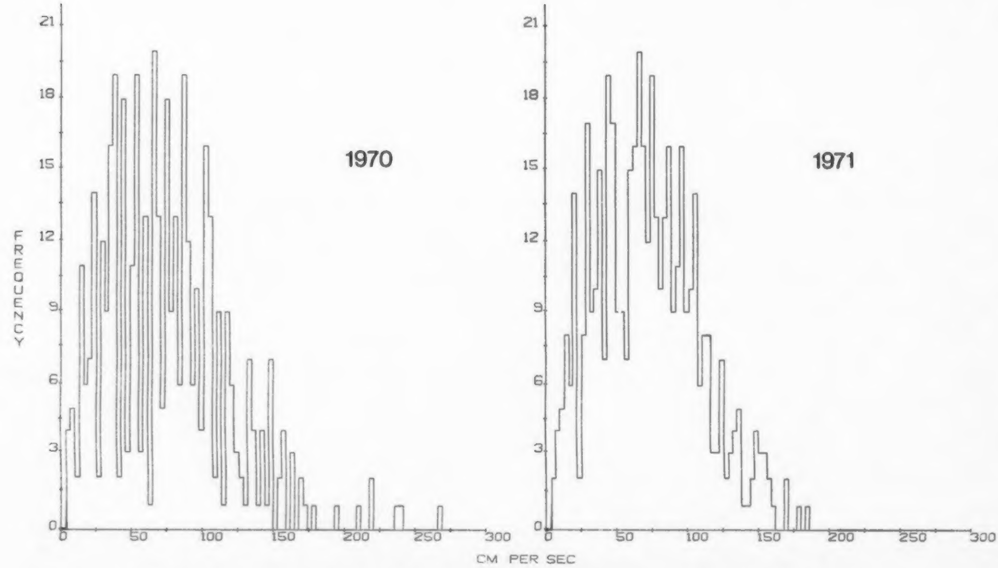

FIG. 7. Frequency distribution of calculated shad swimming speeds, 1970 and 1971.

Sound adjacent to and west of the Connecticut River prior to entry into the river.

Analysis of the behavior of shad tracked in Long Island Sound revealed a well-defined behavior pattern highly correlated to tidal conditions. Shad exhibited countercurrent orientation in response to the reversing tidal current, but the precision and directivity of the orientation was greater when bearing west against the ebb tide than during flood tide conditions. Shad adjusted their swimming speed to changes in tidal current velocity in a manner which resulted in swimming speeds in excess of the ebb tide velocity. Under flood tide conditions, swim-speeds were approximately equal to tidal current velocity. The result of this westerly bias inherent in the open water behavior pattern was a westerly displacement.

TABLE 2. Correlation analysis of calculated swim-speed vs. tidal current velocity in Long Island Sound, 1970, 1971.[a]

Year	Condition	N	*r*	*P*
1970	All	416	.313	$P<.01$
	Day	272	.349	$P<.001$
	Night	144	.257	$P<.01$
1971	All	470	.155	$P<.01$
	Day	288	.206	$P<.01$
	Night	182	.083	$P>.05$

[a] All figures cm/sec.

TABLE 3. Mean shad swim-speed and mean tidal velocity under ebb and flood tide conditions, 1970 and 1971.

	Westerly tide			Easterly tide		
	mean	SD	*n*	mean	SD	*n*
1970						
Tide	68.8	30.2	173	63.8	29.1	213
Fish	69.1	42.2	173	83.5	43.6	213
1971						
Tide	64.1	30.6	218	58.5	25.6	214
Fish	65.5	35.7	218	80.2	33.9	214

Analysis of individual shad revealed that during flood tide conditions, the behavior of shad varied from countercurrent orientation to concurrent orientation. Eight of 25 shad exhibited the latter tendency. Such behavior, however, also resulted in a westerly displacement in Long Island Sound.

To successfully home to the Connecticut River, shad tracked to the west must alter their behavior pattern to affect the opposite directional displacement. Three shad tracked to the east exhibited a partial alteration of the open water behavior pattern described for shad tracked to the west. Fish no. 07–70, 08–70, and 13–70 exhibited a lower frequency of large turning angles during flood tide conditions implying a greater degree of directed movement when bearing east. However, no directional bias was evident in the adjustment of swimming speed to tidal velocity. Fish no. 07 swam at speeds in excess of both tidal velocities, whereas fish no. 08 and 13 swam at speeds less than both tidal velocities. In spite of the limited number of observations on shad initially tracked east in Long Island Sound, the results indicated that shad tracked to the east and to the west exhibited the same major behavior components of countercurrent orientation and swim-speed adjustment to tidal velocity. Only the unidirectional bias inherent in these behavior components was altered to produce the initial easterly displacement. Thus, at least two orientation mechanisms are implicated in the migration. One is involved with orienting shad to tidal rate and direction, the other determines the directional bias inherent in the open water behavior pattern.

Several sensory modalities could be involved in governing the observed rheotaxic response of shad.

TABLE 4. Mean tidal velocity and mean shad swim speed during hours of daylight and darkness, 1970 and 1971. *P* — level of significance as determined by *t*-test.

	Westerly flowing tide						Easterly flowing tide					
	n	Tide vel	SD	Fish vel	SD	*P*	*n*	Tide vel	SD	Fish vel	SD	*P*
1970, Day	123	67.0	29.5	68.6	42.4	>.05	124	62.7	28.0	84.9	40.2	<.01
1970, Night	50	73.2	31.7	70.3	42.1	>.05	89	65.4	30.6	81.4	47.9	<.01
1971, Day	134	65.4	30.6	71.9	36.8	>.05	129	57.6	24.7	82.3	34.4	<.01
1971, Night	84	64.5	30.6	54.9	31.5	<.05	85	59.9	27.0	76.7	33.2	<.01

The countercurrent behavior observed in speckled trout (Elson 1939), salmon and eels (Davidson 1949), coho and chum salmon fry (Mackinnon and Hoar 1953) and cod, whiting, whiting-pout, smelt, and herring (Harden Jones 1963) appears to have been achieved through reference to optical stimuli. However, shad tracked in Long Island Sound exhibited countercurrent orientation at night as well as day and displayed similar frequencies of large turning angles under both conditions. Riley and Schurr (1959) observed extinction coefficients in Eastern Long Island Sound that varied from .39 to .82. High extinction coefficients were believed to be due to silt kept in suspension by strong, scouring tidal currents. Therefore, the maintenance of countercurrent orientation at night by optical stimuli would be possible only if shad were migrating very near the surface. Tactile stimuli may have been utilized if the fish were migrating close to the bottom.

The tendency of shad to orient in an easterly direction during flood tide conditions appears to be ill-adaptive for fish affecting a westerly displacement. This phenomenon, however, may be a basic behavior trait resulting from the oceanic migration. The northern migration of shad in the spring from North Carolina and Virginia is coastal (Talbot and Sykes 1958; Leggett and Whitney 1972). In inshore waters along the middle Atlantic states, the prevailing ocean current is southerly. This southerly flow extends well across the continental shelf during the spring and may attain velocities of up to 18 km/day (Bumpus and Lauzier 1965). Thus shad migrating north in the spring must maintain countercurrent orientation at all times to proceed northwards. Therefore, it appears that the behavior exhibited by shad in Long Island Sound is a continuation of a more basic behavior pattern with only the unidirectional bias inherent in the behavior being altered.

The partial breakdown of the ability of shad to adjust swimming speeds to changes in tidal current velocity during darkness suggested that optical clues may be involved in this response. Such clues would be removed or reduced during darkness. Shad, however, did not exhibit any speed reduction at night. Thus, shad did not display a diurnal rhythm of activity such as has been observed in chinook salmon in a river system (Johnson 1960) and sockeye salmon in a costal situation (Madison et al. 1972). Madison et al. observed a departure from the diel rhythm of swimming speeds characteristic of sockeye salmon when one fish was tracked into an inlet situation. They believed this may have been due, in part, to the bidirectional flow in the inlet. This is compatible with our observations of shad migrating in Long Island Sound which also exhibits a strong bidirectional flow.

Although the behavior of shad was most obviously related to tidal current rate and direction, these two variables in themselves are not indicative of the location of the Connecticut River. Therefore, other environmental variables, indicative of the Connecticut River, must be responsible for establishing the unidirectional bias inherent in the open water behavior pattern of shad. Celestial clues do not appear to play a role as shad behavior remained relatively constant throughout periods of clear and cloudy daytime and nighttime skies.

The observed tendency of shad to increase swimming speeds in response to lowered salinities suggested that water-borne chemical clues may play a role in the location of the natal river. During the shad spawning season of 1970 and 1971, the Connecticut River was responsible for 75–78% of the total freshwater inflow into Long Island Sound (Water Resources Division, United States Geological Survey, Hartford, Conn.). Furthermore, Connecticut River water has been detected off Montauk Pt. (Riley 1959), well within the proposed oceanic migration route of shad. Thus, shad migrating in areas of decreased salinity could obtain clues characteristic of the natal river. However, the freshwater plume discharged from the Connecticut River becomes fragmented and spread to the east and to the west of the river by the strong bidirectional current. As a result, the response of shad to lowered salinities cannot be defined in terms of orientation towards or away from the Connecticut River. Indeed, if shad do use chemical clues to establish a preferred direction of movement in Long Island Sound, the dispersal and dilution of Connecticut River water over much of northeastern Long Island Sound may be in part responsible for the initial migration of shad beyond their natal river. As shad proceed west, chemical clues indicative of the Connecticut River would become less evident and foreign chemical clues originating from other rivers would become more prevalent. This in turn may evoke the opposite directional bias.

Other clues may be responsible for the reversal in unidirectional displacement that must be affected by shad migrating west of the Connecticut River. The shallow and enclosed western portion of Long Island Sound is 3–5 C warmer than the eastern end (Riley 1959). West of the Connecticut River, spring freshening begins earlier and the more sluggish circulation patterns of the western end cause an approximate 5‰ reduction in the level of salinity relative to the eastern end (Riley 1959). The major east–west trench systems running from the deep waters of the eastern end to the shallow waters of the western end could also act as topographical reference points. Any or all of these clues could provide shad with orientational or positional information.

The location of the Connecticut River by shad migrating in Long Island Sound appears to depend to a large degree on an extensive but nonrandom search. This conclusion is based on the long period of time required by shad to home to the Connecticut River from points relatively close to the river mouth and the observed westerly displacement affected by Connecticut River shad already west of the river. We hypothesize that shad migrating along the eastern coast of North America in the vicinity of Long Island Sound detect clues indicative of the Connecticut River that establish a unidirectional bias resulting in a westerly movement towards the Connecticut River. If the river is not located on the first leg of the migration and shad proceed west of the river, some stimuli, presently unknown, evoke the opposite unidirectional bias resulting in an easterly displacement towards the Connecticut River. Under both conditions, the open water behavior pattern continues to be most directly oriented by the rate and direction of the tidal current, while the clues responsible for evoking the unidirectional bias cease to be orienting clues once the bias is established. This sequence may be repeated several times before the river is located.

The culmination of the behavior sequence exhibited by shad occurs on entry into the river. The results of this study have shown that proximity to the Connecticut River does not ensure entry into the river and, therefore, other factors must be involved. A temporal restriction related to the shad's state of receptiveness to certain environmental stimuli may be imposed upon the behavioral sequence described.

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1-Methyladenosine Hydrolase of Starfish (*Pisaster ochraceous*)

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TARR, H. L. A. 1973. 1-methyladenosine hydrolase of starfish (*Pisaster ochraceous*). J. Fish. Res. Board Can. 30: 1861–1866.

A nucleosidase specific for 1-methyladenosine was purified up to 42-fold from mature testes of starfish, and less extensively from mature ovaries, stomach tissue, and pyloric caeca, by extraction, ammonium sulphate fractionation, and DEAE-cellulose chromatography. The enzyme, the products of which were 1-methyladenine and D-ribose, was free from nucleoside phosphorylase activity and had the following properties. The *p*H optimum was 7.8–8.0 with half maximum activity at *p*H 6.2 and 9.5; the enzyme was rapidly inactivated at 40 C and by freezing and thawing; of 10 purine and pyrimidine ribonucleosides and deoxyribonucleosides studied, only 1-methyladenosine was hydrolyzed; the Km was 6.65–7.15 × 10^{-4} M; 1-methylinosine and 1-methylguanosine were noncompetitive inhibitors; the Ki for these were 1.25 × 10^{-4} M and 1.4 × 10^{-4} M, respectively. V_{max} values of from 6.3–10.4 μmoles of 1-methyladenosine hydrolyzed per mg of enzyme protein per hr at 25 C were calculated. It is not known if this enzyme plays a role in the in vivo formation of 1-methyladenine, which induces maturation of starfish oocytes.

TARR, H. L. A. 1973. 1-methyladenosine hydrolase of starfish (*Pisaster ochraceous*). J. Fish. Res. Board Can. 30: 1861–1866.

Une nucléosidase spécifique de la 1-méthyladénosine a été purifiée jusqu'à 42 fois à partir de testicules d'étoiles de mer et à un degré moindre à partir des ovaires mûres, du tissu stomacal et des caeca pyloriques, par extraction, fractionnement au sulfate d'ammonium et chromatographie sur DEAE-cellulose. L'enzyme, dont les produits sont la 1-méthyladénine et le D-ribose, est dépourvu d'activité nucléoside phosphorylase et a les propriétés suivantes: le *p*H optimal est de 7.8 à 8.0 avec la moitié de l'activité maximale à des *p*H de 6.2 et 9.5; l'enzyme devient rapidement inactive à 40 C et par congélation et décongélation; parmi les 10 purine et pyrimidine ribonucléosides et désoxyribonucléosides étudiées, seule 1-méthyladénosine est hydrolysée; le Km est de 6.65–7.15 × 10^{-4} M; 1-méthylinosine et 1-méthylguanosine sont des inhibiteurs non compétitifs; les Ki sont de 1.25 × 10^{-4} M pour 1-méthylinosine et de 1.4 × 10^{-4} M pour méthylguanosine; des V_{max} allant de 6.3 à 10.4 μmoles de 1-méthyladénosine hydrolisée/mg de protéine enzymatique/h à 25 C ont été obtenues. On ignore si cet enzyme joue un rôle dans la formation in vivo de la 1-méthyladénine qui déclenche la maturation des oocytes de l'étoile de mer.

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THE glycosidic linkage in nucleosides may be split enzymatically either by nucleoside hydrolases (nucleosidases) or by nucleoside phosphorylases. Nucleoside phosphorylases are much more widely distributed than are the hydrolases and carry out reversible reactions which involve both ribonucleosides and deoxyribonucleosides (Friedkin and Kalckar 1961; Razzell 1967; Tarr 1967). Comparatively few nucleosidases have been described. Dixon and Webb (1964) and Barman (1969) have listed enzymes of this class as "enzymes hydrolyzing N-glycosidic compounds: E.C. 3.2.2." These enzymes normally hydrolyze ribonucleosides, though hydrolysis of deoxyribonucleosides has been reported occasionally. The present work describes the preparation and properties of a nucleosidase from starfish (*Pisaster ochraceous*) which exerts a high degree of specificity for 1-methyladenosine. A brief report concerning the properties of this enzyme has been published (Tarr 1973).

Materials and General Methods

Nonradioactive nucleosides and R1-P[1] were purchased from Calbiochem or Pabst Laboratories, and 1-MeGuo,

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[1] The following abbreviations and terms are used: 1-MeA, 1-methyladenine; 1-MeAdo, 1-methyladenosine; 1-MeGuo, 1-methylguanosine; 1-MeIno, 1-methylinosine; DEAE, diethylaminoethylcellulose; RI-P, dicyclohexylammonium ribose 1-phosphate. Specific activities (SA) of radioactive compounds are reported as counts per minute (cpm) per micromole, and of enzyme preparations as micromoles of 1-MeAdo hydrolyzed per hr per mg of protein at 25 C. V_{max} is the maximum velocity of the enzyme reaction extrapolated to saturated substrate levels.

1-MeIno, DEAE, and 2-mercaptoethanol from Sigma. Enzyme grade ammonium sulphate and adenosine-8-^{14}C were obtained from Mann and New England Nuclear, respectively.

1-MeAdo was prepared from adenosine by methylation with methyl iodide in dimethylacetamide (Jones and Robins 1963), and 1-MeAdo-8-^{14}C similarly from adenosine-8^{14}C. These compounds were 98-99% pure as judged by their ultraviolet absorption spectra, and their melting points and R*f* values in several solvent systems were similar to those reported in the literature (Jones and Robins 1963; Hall 1971).

1-MeA-8-^{14}C was prepared by enzymic hydrolysis of 1-MeAdo-8-^{14}C. 1-MeAdo-8-^{14}C (50 μmoles; SA 40,000) was dissolved in 5 ml of DEAE-purified 1-MeAdo hydrolase (12 units; 3.9 mg of protein; see below). The solution was held 3 days at 4 C and 4 hr at 22 C, and was then deproteinized with 1 ml of 1 M perchloric acid at 0 C. The protein was removed by centrifugation, and the supernate adjusted to about *p*H 6.0 with 1 N KOH. After several hours at 0 C the supernate was decanted from the potassium perchlorate, the latter being washed with a little cold water. The combined solutions were applied to two 15 × 25-cm sheets of washed Whatman 3 MM paper, and the chromatograms were subjected to ascending development in 85% NH_4HCO_3 (Hems 1959) for 2 hr at 22 C. In this system 1-MeAdo had an R*f* value of 0.72 and 1-MeA of 0.52. The 1-MeA was eluted with water, and the solution was clarified by passage through a medium porosity sintered glass filter and concentrated to dryness in vacuo at 40 C. The residue was dissolved in 0.5 ml H_2O and the solution allowed to evaporate slowly at 0 C. The crystalline residue was washed with a little cold water and dried over P_2O_5 in vacuo. The compound was 95% pure as judged by its ultraviolet absorption spectra. Its R*f* values in several solvent systems were similar to those reported in the literature (Brookes and Lawley 1960; Jones and Robins 1963; Hall 1971). The yield was 31 μmoles; SA 37,000.

Starfish were collected during April and May when the gonads were well-developed (20–80 g per animal) and occupied most of the cavities of the radial arms which, at the nonspawning season, are taken up by the pyloric caeca. They were held in circulating sea water (6–10 C) and were fed chopped herring or fish scraps about once each week. A reserve supply of gonads was maintained by freezing and storing them in plastic containers at –20 C.

Radioactivities were determined with a Packard Tri-Carb liquid scintillation spectrometer, Model No. 3375, using Bray's solution (Bray 1960) for aqueous solutions, and a solution containing 4 g of 2,5-diphenoxyazole and 0.1 g of 1,4-bis [2-(5-phenoyloxazolyl)]-benzene in 1 liter of toluene for samples cut from paper chromatograms. Protein was determined by the method of Lowry et al. (1951), the 2-mercaptoethanol being removed from the samples by dialysis.

Two methods were employed to determine 1-MeAdo hydrolase. One depended on determination of the amount of radioactive 1-MeA formed during enzymic hydrolysis of 1-MeAdo-8-^{14}C. It was used in initial exploratory work and in some experiments to determine the activities of the eluates of DEAE columns. Enzyme preparations (0.1 or 0.2 ml), 0.01 ml of 1 M potassium phosphate *p*H 7.5, and 0.27 μmole (15,000 cpm) of 1-MeAdo-8-^{14}C were held 1 or 2 hr at 25 C. After addition of 0.2 μmole of 1-MeAdo and of 1-MeA as carriers, 0.04 ml of 5% trichloracetic acid was added and the mixture held 1 min in boiling H_2O. The solution was cooled and centrifuged, the protein precipitate washed with a little H_2O, and the combined supernates subjected to ascending chromatography by the method referred to previously. The ultraviolet absorbing zones corresponding to 1-MeAdo and 1-MeA were cut out and their radioactivities determined. The results are reported as percentages of total radioactivities recovered in 1-MeA.

The second procedure (ion exchange method) involved the determination of D-ribose liberated on hydrolysis of 1-MeAdo. 1 μmole of 1-MeAdo was held 30 min at 25 C with 0.5 ml of enzyme preparation. The solution was chilled in ice water, protein was precipitated by the addition of 0.2 ml of 1 M perchloric acid, and the precipitate was removed by centrifuging at 5000 g at 0 C. The precipitate was washed with 0.3 ml of H_2O and the combined solutions were neutralized with 1 M KOH. After standing 30 min or longer at 0 C the supernate was decanted from the potassium perchlorate, which was washed with a little water. The combined solutions were transferred to a 5 × 0.3 cm^2 column of Dowex 1 × 10 Cl^- resin which was superimposed over a similar column containing Dowex 50 × 8 H^+ resin. The columns were eluted with water, the first 6 ml of effluent being collected. This procedure removed residual 1-MeAdo and most other compounds which might interfere with the determination of ribose. Ribose was determined in 0.6-ml aliquots of the effluent by the orcinol reaction (Mejbaum 1939).

Enzyme preparations were made at 0–3 C. The tissue (male or female gonads, pyloric caeca, or stomach) was homogenized at high speed for 30 sec in a Serval Omnimix with 3 vol of a solution containing 20 mM potassium phosphate buffer *p*H 7.5 and 20 mM 2-mercaptoethanol. This type of buffer solution was used in all subsequent procedures. The homogenate was centrifuged 30 min at 30,000 *g*, and floating particles were removed from the supernate by filtering it through a thin layer of glass wool. The solution was adjusted from about *p*H 6.8 to *p*H 7.5 with 1 M NH_4OH solution, and ammonium sulphate was added to bring it to 0.5 saturation. The precipitated protein was concentrated by centrifuging 10 min at 20,000 *g*. The precipitate was dissolved in a small volume of buffer solution, adjusted to *p*H 7.5 with 0.1 M KOH and dialyzed for 2 hr against buffer solution to remove most of the ammonium sulphate. Prolonged dialysis caused a marked loss of enzyme activity. The dialyzed solution was adjusted to *p*H 7.5, and it was then applied to a 42 × 2.5 cm^2 DEAE column which had been equilibrated with buffer solution. The column was eluted under hydrostatic pressure sufficient to cause a flow rate of about 100 ml/hr using a linear gradient formed by passing 100 ml of buffer containing 1 M NaCl (*p*H 7.5) into 100 ml of buffer without additive, collecting 5-ml fractions. The fractions were assayed for protein (A at 280 nm) and for 1-MeAdo hydrolase activity. Enzyme preparations were held at 0 C and were used within 2 weeks of the time of commencement of the preparation. Attempts to purify the enzyme further by fractionation of DEAE preparations on hydroxyapatite columns were not successful because the loss of activity was large and the SA was not increased.

Experimental

PREPARATION OF 1-MEADO HYDROLASE

When 17 g of frozen testes which had been stored 15 weeks were treated by the procedure outlined above, a 36-fold purification was attained with a 52% yield (Table 1). The enzyme was eluted as a distinct peak at about 0.5 M NaCl concentration and emerged as an isolated peak (Fig. 1). The SA of the enzyme preparation was 2.75. With six similar preparations from testes the SA of the DEAE fractions varied from 1.95 to 3.26, and the purification attained was between 19-and 42-fold.

The isolation procedure used for testes was much less effective when applied to the other organs. Thus the SA of the DEAE eluates obtained from ovaries in two experiments were 0.59 and 0.74, a 5.8-fold purification being obtained with the latter preparation. Similarly, the SA of a DEAE preparation from pyloric caeca was only 0.47. Since the testes preparations had the highest SA, most experiments were made with enzyme obtained from this source. Enzyme reactions were carried out at 25 C since the reaction proceeded at a constant rate at this temperature for the first 30 min. At higher temperatures the enzyme exhibited marked instability.

*p*H-ACTIVITY

Portions of an enzyme preparation (SA 2.0) were cautiously adjusted to *p*H values between 6.0 and 10.0 with 0.5 N KOH or H_3PO_4. The rate of hydrolysis of 1-MeAdo by portions of the treated enzyme (0.15 mg protein) was determined by the ion exchange procedure. The enzyme had an optimum *p*H of 7.8–8.0 with half maximum activity at *p*H 6.2 and 9.5.

TABLE 1. Purification of 1-methyladenosine hydrolase from starfish (*Pisaster ochraceous*) testes.

Fraction	Vol (*ml*)	Protein (*mg/ml*)	Protein in fraction (*mg*)	Units	SA units/ mg protein	Recovery (%)	Purification (*X*)
Homogenate	64	15	960	73	0.076	100	1.0
Supernate	59	3.3	195	74	0.378	101	4.96
$(NH_4)_2SO_4$	10.3	9.8	101	41	0.406	56	5.30
DEAE	20	0.76	15.2	38	2.75	52	36.0

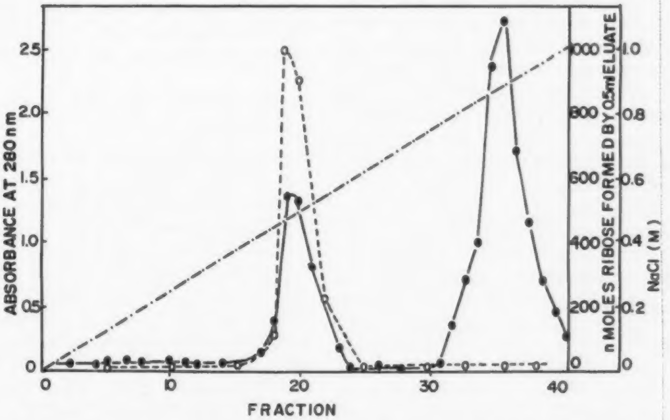

FIG. 1. Chromatography of 10.3 ml (101 mg of protein) of a dialyzed ammonium sulphate fraction of starfish testes 1-MeAdo hydrolase on a 42 × 2.5 cm: DEAE cellulose column (see text for details of procedure). ●, Protein (absorbance at 280 nm); ○, μmoles of ribose per 5-ml fraction.

TEMPERATURE-ACTIVITY

A preparation with an SA of 2.6 was used, and portions of the enzyme were held at 25 C and 40 C before carrying out the ion exchange assay using 0.13 mg protein per experiment. At 25 C the loss of activity was only 10% after 2 hr. At 40 C destruction was rapid, being 21% in 30 min, 42% in 60 min, and 63% in 90 min.

SUBSTRATE SPECIFICITY

One µmole of each of 10 ribonucleosides and deoxyribonucleosides was held 30 min and 60 min with 0.35 mg of enzyme protein (SA 2.1) before determining the amount of hydrolysis by the ion exchange procedure. Of the 10 substrates studied, only 1-MeAdo was hydrolyzed, the data being as follows:

	Hydrolysis (%)			Hydrolysis (%)	
Nucleoside	30 min	60 min	Nucleoside	30 min	60 min
1-MeAdo	55	87	Cytidine	0	0
1-MeGuo	1	1	Uridine	0	0
1-MeIno	0	0	Deoxy-adenosine	0	0
Adenosine	0	0	Deoxy-guanosine	0	0
Guanosine	2	2	Thymidine	0	0

Of the 10 substrates studied only 1-MeAdo was hydrolyzed.

RIBONUCLEOSIDE INHIBITORS

The inhibition of 1-MeAdo hydrolase by several ribonucleosides was investigated. The conditions employed were those of the standard assay with addition of 1 µmole of inhibitory nucleoside. With the testes enzyme the SA was 2.0, and 0.39 mg of protein was used per experiment; with the pyloric caecae enzyme these values were 0.47 and 1.30, respectively. The results, tabulated below, showed that both 1-MeGuo and 1-MeIno caused strong inhibition, while the other three compounds were much less inhibitory:

	Inhibition (%)	
Nucleoside	Testes preparation	Caeca preparation
None	0[a]	0[b]
1-MeIno	80	100
1-MeGuo	80	82
Guo	6.5	11
Ado	10	5.0
Ino	25	6.0

[a] 48% of the 1-MeAdo was hydrolyzed in the absence of an inhibitory nucleoside.

[b] 26% of the 1-MeAdo was hydrolyzed in the absence of an inhibitory nucleoside.

Km

This value was determined in presence and absence of 1-MeGuo and 1MeIno using the double reciprocal plot method of Lineweaver and Burk. The results using 1-MeGuo as inhibitor are given in Fig. 2. The Km value was 6.65×10^{-4} M. Using 1-MeIno as inhibitor with another enzyme preparation under identical conditions, the Km was 7.15×10^{-4} M. Both 1-MeGuo and 1-MeIno were noncompetitive inhibitors of 1-MeAdo hydrolase.

Km values obtained with five other testes enzyme preparations were within the range $6.65–7.15 \times 10^{-4}$ M. Preparations of much lower SA obtained from ovaries (SA 0.31) and pyloric caeca (SA 0.47) gave Km values of 9×10^{-4} M and 1×10^{-3} M, respectively. With both these preparations 1-MeIno (0.2 mM) inhibited 1-MeAdo hydrolase noncompetitively.

V_{max}

V_{max} values of between 6.3 and 10.4 µmoles of 1-MeAdo hydrolyzed per hour per mg of protein were calculated from Lineweaver-Burk plots of four different testes preparations. The relative V_{max} values in presence of 1-MeGuo (Fig. 2) and 1-MeIno were 0.55 and 0.44, respectively, where the value in the absence of these inhibitors was assumed to be 1.0.

Ki

This value was determined by the method of Dixon (1953). With a testes preparation the Ki for 1-MeGuo was 1.4×10^{-4} M (Fig. 3) and 1.25×10^{-4} M for a caecal preparation examined under identical experimental conditions. With a preparation from ovaries the Ki for 1-MeIno was 1.8×10^{-4} M.

PROOF THAT THE ENZYME IS AN N-RIBOSIDE HYDROLASE

In the solvent system used to separate 1-MeAdo and 1-MeA, D-ribose and R1-P had Rf values of 0.85 and 0.95, respectively. When reaction mixtures of 1-MeAdo and 1-MeAdo hydrolase were deproteinized and subjected to paper chromatography in this system, both 1-MeAdo and 1-MeA were detectable by ultraviolet light, and D-ribose by application of aniline hydrogen phthalate spray reagent. R-1P was not demonstrated either by application of sensitive spray reagents for orthophosphate (Hanes and Isherwood 1949; Wade and Morgan 1955) or by the above reagent slightly acidified with HCl.

The equilibrium is usually at least 80% in favor of nucleoside synthesis in reactions catalyzed by nucleoside phosphorylase enzymes. It would therefore be expected that 1-MeAdo would be formed

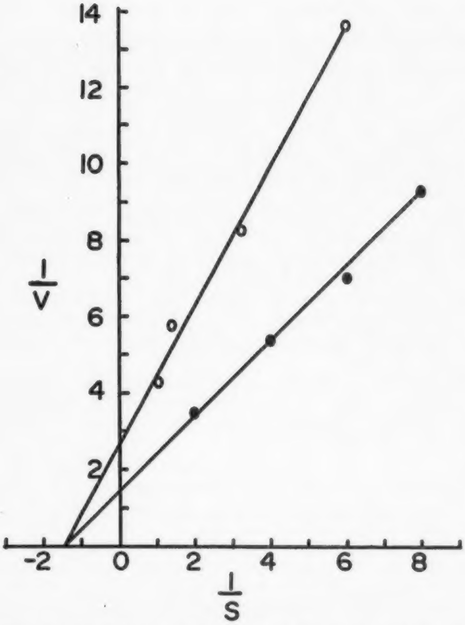

FIG. 2. Inhibition of testes 1-MeAdo hydrolase by 1-MeGuo. Enzyme (0.13 mg. of protein;SA 2.7) with different amounts of 1-MeAdo (0.125–1.0 µmoles), and with and without 0.2 µmoles of 1-MeGuo, in a final volume of 1.0 ml, was held 30 min at 25 C before determining the amount of ribose formed by the ion exchange procedure. No 1-MeGuo present, ●; 0.2 µmoles of 1-MeGuo added, ○.

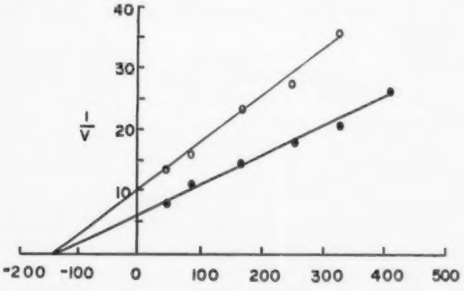

FIG. 3. Determination of the inhibitor constant, Ki, using the testes enzyme and 1-MeGuo as inhibitor. Testes enzyme (0.13 mg protein; SA 2.6) was held 30 min at 2.5 C in a final volume of 0.6 ml with 1-MeAdo (0.42 µmoles per ml in one series, ○, and 0.84 µmoles per ml in the other, ●.) The concentrations of 1-MeGuo used varied between 42 and 420 µmoles per ml. V = nmoles of ribose formed per sample.

from 1-MeA plus R1-P by the starfish enzyme if it possessed 1-MeAdo phosphorylase activity. To test this possibility 2 µmoles of 1-MeAdo-8-^{14}C (45,500 cpm), 2 µmoles of R1-P, and 2 ml of testes enzyme (SA 2.6) were held 1 hr at 25 C, together with a control containing the same enzyme heated 2 min at 100 C. After addition of 1 µmole each of 1-MeAdo and 1-MeA to the reaction mixtures they were chilled and deproteinized by addition of 0.5 ml of 1 M perchloric acid. The perchloric acid was removed as in previous experiments and the solutions were chromatographed for 2 hr on Whatman 3MM paper by ascending development in 85% NH_4HCO_3. The zones corresponding to 1-MeAdo and 1-MeA were cut out from the dried papers and their radioactivities determined. Only 1% of the 37,000 cpm recovered in the unheated enzyme experiment were in the 1-MeAdo zone. The results with the heated enzyme experiment were similar, 1.7% of the 32,000 cpm recovered being in the 1-MeAdo zone. No appreciable 1-MeAdo was formed indicating that the enzyme had no nucleoside phosphorylase activity.

Discussion

Release of gametes and oocyte maturation in starfish are induced by a peptide hormone (gonad stimulating substance; GSS) released by the radial nerves (Chaet 1967; Kanatani et al. 1971). This hormone acts on the ovaries to stimulate production of a compound of low molecular weight (Schuetz and Biggers 1967) which Kanatani et al. (1969) have identified as 1-MeA. It is this compound that stimulates maturation of the oocytes. Experiments have shown that GSS stimulates formation of 1-MeA, or a precursor of 1-MeA, in isolated ovarian fragments in the presence of methionine, and that this activity is inhibited by L-ethionine (Shirai et al 1972). This reaction does not occur in absence of GSS.

Analogy with bacterial and mammalian enzyme systems that carry out methylation of purine and pyrimidine bases would suggest that, in the starfish ovary, methylation of adenine might require prior formation of S-adenosylmethionine from methionine and adenosinetriphosphate, and that this in turn would be used in the enzymic methylation of nucleoside residues in polynucleotides such as s-RNA or DNA (Hurwitz et al. 1964a and b; Gold and Hurwitz 1964a and b). Under these conditions the 1-MeA required for maturation of starfish oocytes would presumably arise through degradation of RNA containing 1-MeA. However, Shirai (1972) has found that a very small amount of 1-MeA is formed in isolated starfish ovaries in the presence of GSS, but not in its absence, and that this does not appear to arise through enzymic degradation of starfish RNA by an RNAase isolated from the ovaries. He concluded that the 1-MeA required for oocyte maturation arises by some metabolic pathway involving GSS and an unidentified substrate. This finding appears to throw some doubt on the participation of 1-MeAdo hydrolase (Schuetz 1970, 1971; Kanatini and Shirai 1972) as one of the enzymes concerned in the formation of 1-MeA in the starfish ovary. Obviously further investigations are required to identify the pathways by which 1-MeA is formed in starfish ovaries and other tissues.

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Influence of Salinity on Protein Requirements of Rainbow Trout (*Salmo gairdneri*) Fingerlings[1]

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Rainbow trout (*Salmo gairdneri*) juveniles maintained at 10 and 20 ppt salinity were fed seven diet treatments from 30 to 60% protein in 5% increments for 10 weeks. The fish were stocked in cones, initially 50 fish per cone. Biweekly weights of diets and fish were determined and mortality was recorded daily. Percentage weight gain, gross diet efficiency, and protein efficiency ratio (P.E.R.) were computed. The minimum protein levels required for fish to achieve highest performance using these criteria were 40 and 45% for those maintained at 10 and 20 ppt, respectively. Mortality was significantly ($P < 0.05$) higher for fish maintained at the higher salinity. Analyses of the fish carcasses were conducted at the beginning and end of the experiment on representative samples to estimate the grams protein retained and apparent net protein utilization (N.P.U.) to verify the above findings. All the available data showed that dietary protein was of major consequence on all measurements until the minimum required level of protein in the diet was reached, while salinity was of minor consequence. P.E.R. and apparent N.P.U. were 2.10 and 34.4, respectively, for casein diets at the 40% protein level.

ZEITOUN, I. H., P. I. TACK, J. E. HALVER, AND D. E. ULLREY. 1973. Influence of salinity on protein requirements of rainbow trout (*Salmo gairdneri*) fingerlings. J. Fish. Res. Board Can. 30: 1867–1873.

Pendant 10 semaines, nous avons donné des régimes de teneurs respectives en protéines de 30 à 60%, par échelons de 5%, à de jeunes truites arc-en-ciel (*Salmo gairdneri*) maintenues à des salinités de 10 et 20 parties pour mille. Les sujets ont été maintenus dans des aquariums coniques, à raison de 50 par unité, au début de l'expérience. Le poids des rations et celui des sujets ont été observés deux fois la semaine, et on a enrégistré les mortalités quotidiennement. Le pourcentage de gain pondéral, le rendement total des rations et le taux de rendement des protéines (P.E.R.) ont été calculés. Les minimums de protéines nécessaires à une performance maximale de la part des sujets, en fonction de ces critères, sont de 40 et 45% pour les échantillons maintenus aux salinités de 10 et 20 parties pour mille respectivement. Les mortalités sont significativement supérieures ($P < 0.05$) pour les sujets maintenus à la plus haute salinité. On a effectué des analyses de cadavres sur des échantillons représentatifs au début et à la fin de l'expérience afin d'évaluer la rétention en protéines et le taux net d'utilisation des protéines (N.P.U.) et de vérifier les résultats ci-dessus. Toutes les données disponibles démontrent que,

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jusqu'à concurrence d'un seuil minimal, le taux en protéines a une influence capitale pour toutes les mesures, alors que le degré de salinité n'a qu'une importance mineure. Le P.E.R. et le N.P.U. apparent sont de 2.10 et 34.4 respectivement, pour des rations de caséine à teneur en protéines de 40%.

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STUDIES of environmental variables on body composition and quantitative nutritional requirements of fish are limited compared to those reported for mammals and birds. Halver (1957) developed a test diet that could maintain salmon and trout without symptoms of nutritional deficiency. Brett (1971) indicated that this diet was well balanced and favorable for sockeye salmon (*Oncorhynchus nerka*). This diet was modified and used to measure protein requirements of rainbow trout (*Salmo gairdneri*), sockeye salmon (*O. nerka*) (Halver et al. 1964), and chinook salmon (*O. tschawytscha*) (DeLong et al. 1958). Recently Cowey et al. (1972) estimated protein requirements of the young plaice (*Pleuronectes platessa*) using freeze-dried cod muscle and shrimp meal as sources of protein. The goal of this research was to establish the quantitative protein requirement and nitrogen retention of rainbow trout as influenced by salinity.

Materials and Methods

Seven separate diets composed of 30–60% protein in 5% increments (Table 1) were used in this 10-week experiment. In diets containing 30 or 35% protein, less water was used in the formulation to avoid excessive leaching of the water soluble constituents. In all diets, the ratio of casein to gelatin was maintained constant. Compositions of the vitamin, oil, and mineral mixtures are presented in Table 2–4.

Two salinities were used in the experiments, 10 and 20 ppt created by mixing appropriate proportions of fresh and sea water pumped from natural sources. The electrical resistance of the water was checked twice daily to confirm salinity. Prior to the mixing of fresh and sea water, each was filtered in a fiberglass filter tank,[2] and then exposed to ultraviolet light.[3] The fish were treated twice with 1 ppm Furanase[4] in the 1st week of the experiment to inhibit bacterial growth.

Duplicate cones (after Gahimer et al. 1971 with minor modifications) were available for each dietary treatment at each salinity. During the test, water temperatures ranged between 9 and 12.5 C, and light intensity and photoperiods were maintained constant by placing a 10-w light bulb over each cone with 9 hr of illumination daily.

TABLE 1. Composition of different formulated diets.

Basic composition	Dietary protein concentration, %[a]						
	30	35	40	45	50	55	60
Casein	22.8	26.6	30.4	34.2	38.0	41.8	45.6
Gelatin	7.2	8.4	9.6	10.8	12.0	13.2	14.4
Dextrin	48.0	43.0	38.0	33.0	28.0	23.0	18.0
Vitamin mixture[b]	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Oil mixture[c]	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Mineral mixture[d]	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Calorie–protein ratio, kcal/kg/% protein[e]	131	112	98	87	79	72	66
Dry matter: water in finished feed	1:1	1:1	1:2	1:2	1:2	1:2	1:2

[a] The Western Fish Nutrition Laboratory diet numbers which correspond to the diets providing the increasing protein levels are 269, 270, 271, 272, 8, 273, and 274, respectively.
[b] See Table 2.
[c] See Table 3.
[d] See Table 4.
[e] Based on a caloric density of 4 kcal/g for carbohydrate and protein, and 9 kcal/g for fat.

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[2] Crystaleen Model C-7. Howard Construction Corp., 4547 N. Scottsdale Rd., Scottsdale, Ariz.

[3] Aquafine liquid sterilizer, Model MP4 PVC. Aquafine Corp., 1230 Sunset Blvd. Los Angeles, Calif.

[4] Dainippon Pharmaceutical Co., Ltd., Research Lab., Osaka, Japan.

Each cone was stocked initially with 50 rainbow trout fingerlings.

Diet preparation, feeding, and weighing methods followed those described by Halver (1957). Each diet was fed twice a day, ad lib., on a rigid time schedule. At the beginning and termination of the experiment fish were starved for 48 hr, after which representative samples of fish from duplicate cones were frozen for subsequent chemical analysis, which followed thawing and determination of the wet weight of each fish. The fish were dried in ovens at 95 C to a constant weight. Dry matter was calculated and the dry fish were homogenized in a Waring blender with isopropyl alcohol. Homogenates which received the same diet treatment in each salinity were combined and mixed again to a fine composite using a mortar and pestle with additional isopropyl alcohol as a mixing agent. Samples were dried and kept in screw-capped bottles under refrigeration (2–3 C). The dried samples were analyzed for nitrogen by the micro-Kjeldhal method (A.O.A.C. 1970). Crude protein was established by multiplying nitrogen values by 6.25.

TABLE 2. Composition of the vitamin mixture.[a]

Ingredient	Grams
Alpha-cellulose	8.000
Choline chloride	0.500
Inositol	0.200
Ascorbic acid	0.100
Niacin	0.075
Calcium pantothenate	0.050
Riboflavin	0.020
Menadione	0.004
Pyridoxine·HCl	0.005
Thiamine chloride·HCl	0.005
Folic acid	0.0015
Biotin	0.0005
Cyanocobalamin[b]	0.500 ml

[a] The Western Fish Nutrition Laboratory premix no. 1.

[b] Prepared as 20 mg/liter H_2O. The Western Fish Nutrition Laboratory premix no. 2.

TABLE 3. Composition of the oil mixture.[a]

Ingredient	Grams
Corn oil	7.0
Cod liver oil[b]	2.0
D,L-Alpha-tocopheryl acetate	0.04

[a] The Western Fish Nutrition Laboratory premix no. 4.

[b] 3139 USP units vitamin A.

TABLE 4. Composition of the mineral mixture.[a]

Ingredient	Grams
Salt mixture no. 2 USP XIII[b]	100.000
$AlCl_3 \cdot 6H_2O$	0.015
KI	0.015
CuCl	0.010
$MnSO_4 \cdot H_2O$	0.080
$CoCl_2 \cdot 6H_2O$	0.100
$ZnSO_4 \cdot 7H_2O$	0.300

[a] The Western Fish Nutrition Laboratory premix no. 5.

[b] Nutritional Biochemicals Corp., 1972 Diets Manual, page 6, Cleveland, Ohio.

Statistical comparisons were made using the analysis of variance. Mean differences were determined using Duncan's multiple range test. Standard errors (±SE) were calculated to identify the range of the means.

Results

For each group of fish, average daily gain and average daily feed was based upon the number of fish days, which was the sum of days each fish in the group survived. This was necessary to minimize the errors in accounting for the loss of diet used by the deceased fish as well as the weight loss caused by the removal of the dead fish.

WEIGHT GAIN

The weight-gain method of identifying protein need depends upon the fact that an inadequate supply of protein in the diet will reduce the gain in weight or terminate growth completely. In these experiments, percentage weight gain was employed instead of gram gain because average initial weights of the rainbow trout assigned to different diets were significantly different (Table 5). Percentage gain was plotted against the percentage protein in the diet to determine the nitrogen growth index of each fish group (Fig. 1). Nitrogen growth index was defined by Allison (1964) as the slope of the straight line of weight gain plotted against percentage dietary protein. The nitrogen growth index for rainbow trout was 7.7 for those tested at 10 ppt salinity and 7.6 for those at 20 ppt. Minimum protein requirements were estimated by using the method of Fisher et al. (1957), employed for birds. A regression line ($Y = aX + b$) was fitted to the data over the ascending portion of the percentage gain response. A straight line parallel to the x-axis was established by averaging the highest observed

TABLE 5. Summary of the response of rainbow trout fingerlings as affected by dietary protein level and salinity employing different measurements.

	Dietary protein concentration, %								Salinity, ppt		
	30	35	40	45	50	55	60	±SE	10	20	±SE
Average initial weight, g.	6.5^{a}	6.8^{ab}	6.2^{a}	6.3^{a}	6.4^{a}	6.3^{a}	7.2^{b}	0.15	6.5	6.5	0.08
Average final weight, g.	14.2^{a}	17.0^{b}	18.5^{c}	19.2^{cd}	19.6^{cd}	19.4^{cd}	20.5^{d}	0.39	18.4	18.3	0.22
Average weight gain,[f] %									181.1	182.6	3.82
10 ppt	127.0^{a}	165.3^{b}	206.7^{c}	187.1^{bc}	204.0^{c}	195.4^{bc}	182.2^{bc}	10.10			
20 ppt	111.5^{a}	136.1^{a}	187.9^{b}	221.9^{c}	213.8^{bc}	220.8^{c}	186.0^{b}	10.10			
Specific growth rate, %	1.12^{a}	1.31^{b}	1.56^{c}	1.59^{c}	1.61^{c}	1.61^{c}	1.49^{c}	0.04	1.5	1.5	0.02
Gross diet efficiency	0.43^{a}	0.57^{b}	0.84^{c}	0.90^{d}	1.03^{e}	1.07^{e}	1.04^{e}	0.02	0.84	0.84	0.01
Protein efficiency ratio	1.42^{a}	1.62^{b}	2.10^{c}	2.01^{c}	2.06^{c}	1.95^{c}	1.74^{d}	0.04	1.86	1.83	0.02
Apparent N.P.U.,[f] %									30.2	30.7	0.27
10 ppt	21.4^{a}	26.4^{b}	34.4^{c}	32.4^{c}	32.5^{c}	33.4^{c}	31.3^{c}	0.71			
20 ppt	24.6^{a}	25.8^{ac}	34.3^{b}	34.2^{b}	35.5^{b}	32.4^{b}	28.4^{c}	0.71			
Mortality,[g] %									2.1	9.4^{a}	0.79
10 ppt	1.0	3.0	2.0	2.0	6.0	1.0	0.0	2.10			
20 ppt	16.0^{a}	13.8^{a}	8.0^{b}	11.8^{ab}	5.0^{b}	6.0^{b}	5.0^{b}	2.10			

[a,b,c,d,e] Means on the same line under the same major heading followed by different superscripts are significantly ($P < 0.05$) different.
[f] Significant interaction between salinity and protein level in the diet at $P < 0.05$.
[g] Diet effect on the average of the two salinity levels was not significant at $P < 0.05$.

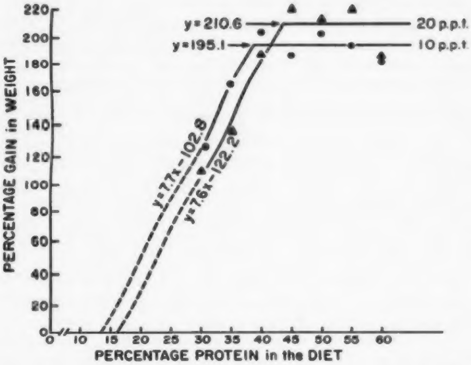

FIG. 1. Nitrogen growth index of the rainbow trout (*Salmo gairdneri*) over a period of 10 weeks (±SE = 10.10).

means which did no differ from each other as determined by the analysis of variance. The average value obtained was used as the Y determinant in establishing the position of this horizontal line. The point of interception of these two lines provided an estimate of the protein requirement. The line interceptions for rainbow trout indicated a minimum requirement of approximately 40 and 45% crude protein at 10 and 20 ppt salinity, respectively.

Application of the mean specific growth rate (Brown 1957; Brett et al. 1969) and the law of diminishing returns recommended by Almquist (1970), plotting the data on a semilog basis, gave results which were identical to those of the nitrogen growth index method used above.

GROSS (OR TOTAL) DIET EFFICIENCY

This parameter is a means of expressing the efficiency of conversion of diet to fish tissue. Gross diet efficiency was symbolized by Warren and Davis (1967) as: $E_t = G/I$ where E_t is the diet efficiency, G is the weight gain, and I is the diet intake.

Gross diet efficiency calculations were based on the wet weight of the average fish and the average dry weight of the diet as fed. Therefore, the diet efficiency ratios tended to be higher than if both gain in weight and weight of the diet ingested were calculated on a dry basis. The diet efficiency ratios of the rainbow trout established that salinity was of minor consequence while the dietary protein level was a major influence (Table 5). When data on the two salinity treatments were combined, gross diet efficiency reached a peak at 50% dietary protein.

PROTEIN EFFICIENCY RATIO (P.E.R.)

This is defined as the coefficient of grams gain per gram protein consumed. P.E.R. calculations are theoretically more precise than estimates of gross diet efficiency since dietary protein consumed is the only item of the diet that is taken into account. P.E.R. figures were substantially influenced by the dietary protein level and not by the osmotic pressure of the medium (Table 2), reaching the highest value around 40% dietary protein.

PROTEIN RETENTION AND APPARENT NET PROTEIN UTILIZATION

Two major criticisms of the P.E.R. method are that 1) it does not allow for maintenance requirements, which are neglected by assuming that all the protein ingested is utilized for growth and, 2) it is based on the assumption that weight gain is constant in composition, which is not necessarily valid (Bender and Doell 1957; Allison 1964). Therefore, other approaches have been used to evaluate the effect of differing dietary protein levels upon growing fish, namely net protein utilization (N.P.U.) and protein retention. The protein retention values were calculated from the equation of Gerking (1952) and Pandian (1967):

$$\text{Protein retained} = \left[\begin{array}{l}\text{body protein at end of}\\ \text{the test, g}\end{array}\right] - \left[\begin{array}{l}\text{body protein at the}\\ \text{beginning of test, g}\end{array}\right]$$

Resulting values were used to determine the apparent values of net protein utilization as follows:

$$\text{Apparent N.P.U.} = \frac{\text{protein retained in grams}}{\text{protein consumed in grams}} \times 100$$

Since the test lacked a group of fish that had been fed a protein-free diet, Miller and Bender's (1955) equation for calculating the N.P.U. was not appropriate for our case. Analysis of the data indicated a profound interaction of salinity and dietary protein level upon apparent N.P.U. for the rainbow trout (Table 5). Figure 2 shows the pattern of fish response to both diets and salinity.

MAINTENANCE REQUIREMENT

The maintenance requirement is defined as the level at which the animal will neither lose nor gain weight, in other words, when percentage growth equals zero. From this definition, an attempt was made to estimate the protein level required for maintenance. The nitrogen growth index curves

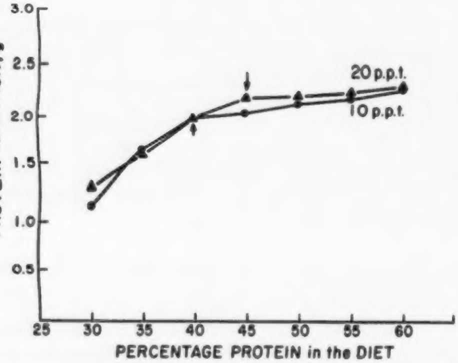

FIG. 2. Relationships between protein retention and dietary protein levels for rainbow trout (±SE = 0.08) maintained at 10 ppt and 20 ppt salinity.

were manipulated by extending the ascending line downward until they met the *x*-axis which represented the percentage dietary protein at zero growth. This manipulation was based on the assumption that weight gain and percentage protein intake were directly related until the point of inflection. Hegsted and Chang (1965b) related gain in weight of rats to nitrogen intake and found that these were linearly related from zero growth until maximum growth was reached. The maintenance protein level of the two groups of rainbow trout fingerlings was close to 15% crude protein. From this approach the osmotic pressure of the medium appeared to exert a small influence over the maintenance requirement, with a higher level for fingerlings maintained at 20 ppt.

MORTALITY

A substantially higher percentage mortality was evident in 20 ppt salinity than in 10 ppt. This difference was particularly pronounced on 30 and 35% dietary protein levels, which were associated with significantly more deaths than on higher protein diets (except 45%) among fish in 20 ppt salinity.

Discussion

The increase in the minimum protein requirements of rainbow trout fingerlings with increased osmotic pressure of the water in which they were reared, affirmed the importance of dietary protein in protecting the internal environment of fish against a hypertonic external environment. Presumably, optimum levels of dietary protein contribute to the development of a Donnan equilibrium which provides this protection (Potts and Parry 1964) and helps support maximum growth. Salinity of 10 ppt in rearing water is approximately isotonic with internal fluids (9 ppt). That this level of salinity was less stressful than 20 ppt was illustrated by a substantially lower percentage mortality on 10 ppt.

Although gross diet efficiency was not significantly affected by environmental salinity, the dietary protein level at which protein retention ceased to increase appeared to be lower at 10 ppt (40% dietary protein) than at 20 ppt salinity (45% dietary protein). Otto (1971) found that the gross diet efficiency of coho salmon throughout the presmolt period was greater at salinities of 5–10 ppt than at higher salinities. While Kinne (1960) reported that gross diet efficiency of the euryhaline teleost *Cyprinodon macularius* was higher in 35 ppt salinity than in fresh water, the efficiency of food conversion is dependent on many factors and the best response may be related to the environment to which the fish has been accustomed (Kinne 1962).

As dietary protein levels increase, the point at which no further growth takes place under given conditions was termed the growth potential of the species by Gerking (1952). If one includes in the concept of growth potential the importance of proper balance of energy and protein in the diet (Ringrose 1971), then the growth potential of rainbow trout fingerlings at 10 and 20 ppt salinities would be achieved at 98 and 87 kcal of metabolizable energy per kg of diet per percent of dietary protein, respectively.

The absolute apparent N.P.U. values found in this study were lower than the N.P.U. values reported by others (Miller and Payne 1961; Cowey et al. 1972; Njaa 1962; Hegsted and Chang 1965b), presumably because a protein-free diet control group was not included and the method of calculation was different. With respect to the effect of dietary protein levels upon relative N.P.U. values, Miller and Payne (1961), working with growing rats, observed a decline in these values as dietary protein concentration increased above needs for maintenance. Cowey et al. (1972) published similar findings with place. However, Njaa (1962) and Hegsted and Chang (1965a), working with growing rats and increasing increments of dietary protein, found that N.P.U. values leveled off or declined only above dietary protein levels adequate to achieve the growth potential. Our conclusions correspond to these latter findings.

P.E.R. values in our study were appreciably higher at all dietary protein concentrations than those reported by Cowey et al. (1972) for plaice fed freeze-dried cod muscle and shrimp meal diets. The digestibility of casein and gelatin (used in our study) is probably much higher than that of certain natural protein sources (perhaps cod muscle and shrimp meal), and this fact may require that practical diets provide higher concentrations of protein than the 40–45% found adequate when using casein plus gelatin as the sole dietary protein source.

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We wish to thank Dr W. G. Bergen for his considerable efforts and suggestions regarding this work, Dr E. W. Roelofs for reviewing the manuscript, and Dr W. T. Magee for assisting with statistical analyses. We are grateful for the generous cooperation provided by personnel at Western Fish Nutrition Laboratory during the study, particularly C. L. Johnson, G. D. Gahimer, A. R. Anderson, and F. Hunger.

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NOTES

Effects of Illumination on Behavior of Wild Brown (*Salmo trutta*) and Rainbow Trout (*Salmo gairdneri*) Exposed to Black and White Backgrounds

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RITTER, J. A., AND H. R. MACCRIMMON. 1973. Effects of illumination on behavior of wild brown (*Salmo trutta*) and rainbow trout (*Salmo gairdneri*) exposed to black and white backgrounds. J. Fish. Res. Board Can. 30: 1875–1880.

Wild brown (*Salmo trutta*) and rainbow trout (*Salmo gairdneri*) placed in a circular tank illuminated at 10^{-2} lx immediately selected black rather than white background. Preference for black fluctuated with activity during the first 2 hr while both selection of black and activity gradually decreased with habituation over the following 84 hr. A sudden increase in illumination to 200 lx reestablished the strong selection of black which decreased rapidly with rising activity. Selection of black was inversely correlated with activity of the fish and was greater under moving than nonmoving water conditions. Differences in activity levels between rainbow and brown trout caused minor differences in response to background.

Temporal preference for black background is interpreted as a protective response to the fright stimuli of initial handling, unfamiliarity with the experimental tank, and sudden increase in illumination. Duration of the response after the sudden increase in illumination was less in brown than rainbow trout. Because of its influence on activity and selection of light or dark backgrounds, light is an important ecological factor for trout.

RITTER, J. A., AND H. R. MACCRIMMON. 1973. Effects of illumination on behavior of wild brown (*Salmo trutta*) and rainbow trout (*Salmo gairdneri*) exposed to black and white backgrounds. J. Fish. Res. Board Can. 30: 1875–1880.

Des truites brunes (*Salmo trutta*) et des truites arc-en-ciel (*Salmo gairdneri*) sauvages placées dans un bassin circulaire sous éclairage de 10^{-2} lx choisissent immédiatement un fond noir, de préférence à un fond blanc. Cette préférence pour le noir varie en fonction de l'activité durant les 2 premières h, alors que le choix du noir et l'activité diminuent tous deux graduellement avec l'accoutumance au cours des 84 h qui suivent. Une augmentation soudaine de l'éclairage à 200 lx rétablit la forte préférence pour le noir, qui diminue rapidement avec une augmentation d'activité. Le choix du noir est en relation inverse de l'activité du poisson et est plus marqué dans l'eau courante que dans l'eau morte. Des différences de niveau d'activité entre la truite arc-en-ciel et la truite brune produisent des différences mineures de réponse à la couleur de fond.

Nous interprétons cette préférence dans le temps pour un fond noir comme une réponse de protection déclenchée par la frayeur que causent la manipulation du début, le caractère étranger du bassin expérimental et l'augmentation soudaine d'éclairage. La durée de la réponse à une augmentation soudaine d'éclairage est plus courte chez la truite brune que chez la truite arc-en-ciel. Par suite de son influence sur l'activité et le choix de fonds pâles ou noirs, la lumière est un important facteur écologique pour la truite.

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As part of a series of experiments to determine the ecological significance of light to fishes, rainbow trout were exposed to different illuminations and observed over dark and light backgrounds (Kwain and MacCrimmon 1967 and 1969). Under a low illumination of 10^{-2} lx, the yearlings selected the black when offered a choice of black or white backgrounds but tended to school when exposed to a higher illumination of 200 lx (Kwain and MacCrimmon 1967). Apparently, from these and other experiments by Kwain and MacCrimmon (1969), there is interaction between activity patterns of fish and the manner in which they respond to their background. The following experiments were designed to examine and compare the significance of this interaction in brown (*Salmo trutta*) and rainbow (*Salmo gairdneri*) trout exposed to black and white backgrounds.

Materials and methods — Wild fish were obtained by electrofishing from early June through September. Yearling and adult brown trout averaging 17.2 (10.4–33.5) cm total length were collected from the upper Sydenham River near Chatsworth, Ontario. Yearling and 2-year-old rainbow trout averaging 12.9 (8.6–23.0) cm were collected from Telfer's Creek near Owen Sound, Ontario.

All experiments were conducted in a circular tank (1.83 m in diameter) illuminated by incandescent bulbs 3600–7200 Å). Water depth was maintained at 15 cm, water temperatures at 12.5–15.0 C, and dissolved oxygen at 6–9 mg/liter by a continuous circulation of aerated tap water. The bottom and sides of the tank up to the water surface (15 cm) were divided equally into eight pie-sections alternately painted black and white. The remainder of the tank was painted white. The rainbow trout were observed in nonmoving or static water similar to the conditions used by Kwain and MacCrimmon (1967 and 1969) in their experiments. Separate groups of brown trout were observed under nonmoving and moving water conditions. The moving water conditions were established by placing two directional inflow jets above the subfloor of the tank. The resulting current pattern established was circular with small areas of undefined turbulence located both peripherally and centrally.

For each test, 20 fish were transported from the collection site and introduced immediately into the tank at low illumination of 10^{-2} lx. The first observation was made 10 min after the introduction. Eleven more observations were made at 10-min intervals over the subsequent 110 min. Similar series of 12 observations were made beginning 24, 48, 60, and 84 hr, respectively, after introduction of test fish into the tank. The illumination was increased 86 hr after introduction, from 10^{-2} lx to 200 lx to simulate a sudden disturbance. The next observation was made 10 min after the sudden increase in illumination followed by 11 more observations over the subsequent 110 min. A final series of 12 observations was made beginning 48 hr after the sudden increase in illumination (134 hr after fish were initially introduced into tank). From the 12 observations for each series means were calculated and used to estimate fish behavior. For each observation an activity index and the numbers

TABLE 1. Activity classification combining fish mobility and fish movement patterns. Class I through IV represent fish mobility. Class A through D+ represent fish movement patterns. See footnote for explanation of meanings for A to D+.[a]

Whole no. value (X)	I	I–II	II	II–III	III	III–IV	IV	Activity index
1	A							.07
2	A–B	A						.14
3	B	A–B	A					.21
4	B–C	B	A–B	A				.29
5	C	B–C	B	A–B	A			.36
6	C–D	C	B–C	B	A–B	A		.43
7	D	C–D	C	B–C	B	A–B	A	.50
8		D	C–D	C	B–C	B	A–B	.57
9			D	C–D	C	B–C	B	.64
10				D	C–D	C	B–C	.71
11				D+	D	C–D	C	.79
12					D+	D	C–D	.86
13						D+	D	.93
14							D+	1.00

[a] A, Fish moving less than 36 cm ($\frac{1}{4}\pi\frac{1}{2}$) and more than 5 cm along a direct path. Includes forward or back movement and broken behavioral patterns in which fish stop and start; B, fish milling either individually or in a group; C, solitary fish movement of more than 36 cm and less than one revolution of tank — descriptive of fish exercising type D behavior interrupted periodically by type B; D, fish moving either individually or grouped in a direct path at least one noninterrupted revolution of tank — includes loose schooling; D+, fish exercising compact schooling.

of fish over the black and white areas were recorded. The activity index is based on the number of fish moving during a 60-sec observation period and the pattern of fish movement (Table 1). A high index value reflects a high level of activity.

Data for fish distribution were analyzed by the chi-square method and corrected by combining probabilities from significant tests (Fisher 1963). An estimate of the dependence of fish distribution on activity was determined by linear regression.

Results — During the first test interval, all three groups of trout initially selected the black background (Fig. 1). After 10 min in the tank, the numbers of brown trout over black background in both moving and nonmoving water environments were high but declined as activity increased during the initial part of the first test interval. Selection of black by rainbow trout in the still water environment also fluctuated with activity, but there was no major decline in the number of fish over black background. Correlations between activity and number of fish over black were negative and significant ($P<0.05$) for each of the three test groups (Table 2).

During the second, third, fourth, and fifth test intervals, the selection of black background by

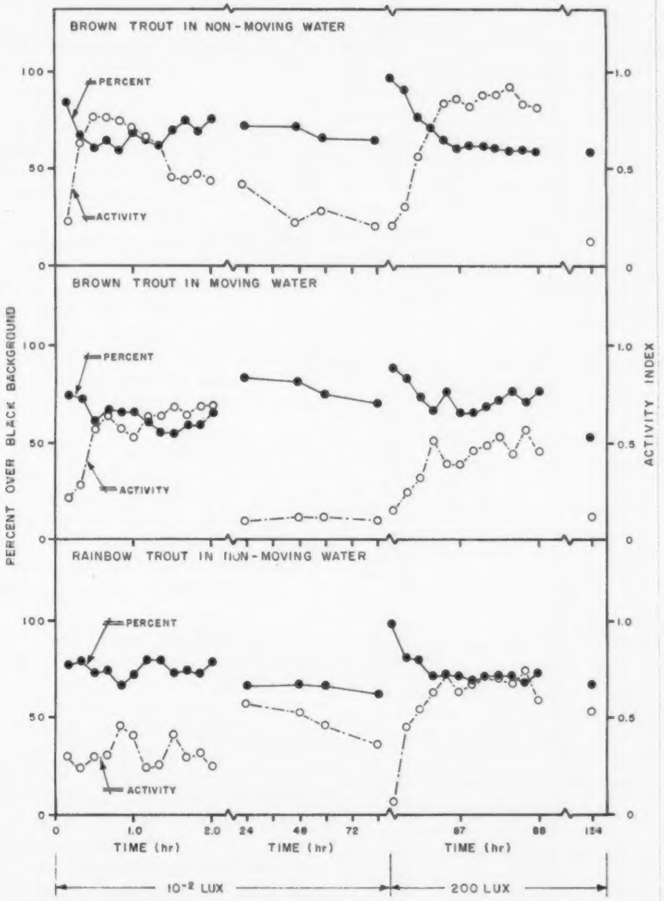

FIG. 1. Comparison of fish activity (*broken line*) and the percentage of wild trout over black background (*solid line*) with time. Values for 24, 48, 60, 84, and 134 hr are means of 12 observations.

TABLE 2. Comparison of temporal changes in activity and distribution of wild trout over a black and white background. Data are mean values for groups of 20 fish each.

			Brown trout in[a] nonmoving water			Brown trout in[b] moving water			Rainbow trout in[a] nonmoving water		
Illumination (lx)	Time (hr)	Test interval	Over black (%)	Activity (I)	Correlation (r)	Over black (%)	Activity (I)	Correlation (r)	Over black (%)	Activity (I)	Correlation (r)
10^{-2}	00:10–02:00	First	68.7	0.59	–0.76[c]	63.5	0.57	-0.59[c]	75.5[c]	0.32	–0.79[c]
10^{-2}	24:10–26:00	Second	72.5[c]	0.42	–0.22	82.2[c]	0.10	-0.80[c]	68.0	0.58	–0.78[c]
10^{-2}	48:10–50:00	Third	72.5[c]	0.29	–0.27[c]	81.8[c]	0.13	-0.73[c]	68.3	0.53	–0.74[c]
10^{-2}	60:10–62:00	Fourth	67.4	0.21	–0.25	74.8[c]	0.12	-0.64[c]	67.2	0.47	–0.26[c]
10^{-2}	84:10–86:00	Fifth	66.6	0.21	–0.51	71.3[c]	0.11	-0.59[c]	63.1	0.36	–0.51[c]
200	86:10–88:00	Sixth	68.2	0.71	–0.90[c]	72.4[c]	0.40	-0.67[c]	75.5[c]	0.60	–0.90[c]
200	134:10–136:00	Seventh	55.7	0.16	–0.20	53.6	0.13	-0.08	65.5	0.56	–0.30[c]

[a] 60 pairs of observations.
[b] 36 pairs of observations.
[c] Significant at 0.05 level.

brown trout was lesser in the still water than the moving water environment. Rainbow trout held in still water were more active and showed a lower preference for black background than either of the brown trout groups. For all three groups, selection of black background decreased with time.

After 86 hr, a sudden increase in illumination reestablished the selection of black background by all groups. Over the subsequent 110 min, declines in the number of fish over black coincided with increases in activity. Brown trout held in still water were the most active, and they occasionally schooled.

During the final test interval (i.e. interval beginning 48 hr after the sudden increase in illumination), the selection of black background was not significant ($P > 0.05$) although preference remained higher for the rainbow trout than for either group of brown trout.

Discussion — The selection of black background by wild brown and rainbow trout is interpreted as a protective response to fright caused by the prior handling of the fish and their unfamiliarity with the experimental tank. Kwain (1965) has interpreted this as an innate hiding behavior. Similar responses occur among trout in nature (Lewis 1969) and when given overhead cover in the laboratory (MacCrimmon and Kwain 1966). The fact that a similar "hiding" response occurs whether the trout are given an opportunity to utilize a section of black bottom or overhead cover, suggests that the fish are displaying a negative response to both incident and reflected light.

Declines in the selection of black background for each test group were correlated either to rising activity or to fish becoming habituated to the new environment. Rising activity noted predominantly during the test intervals following fish introduction to the tank, and again, after the sudden increase in illumination reflects increases in exploratory or investigative behavior.

The difference in brown trout response to background under moving and nonmoving water conditions is similar to that observed for smallmouth bass (*Micropterus dolomieui*) held under different flow conditions (Haines and Butler 1969). Both Hartman (1963) and Haines and Butler (1969) observed increased use of overhead cover by brown trout and smallmouth bass, respectively, as water velocities were increased. Haines and Butler (1969) suggested that the stress placed on fish by the higher water velocity increased the shelter-seeking response regardless of the type of available shelter. Our observations on brown trout suggest that even a low water velocity imposes a greater stress upon the fish than does the static system.

Brown and rainbow trout each selected black background in response to presumed fright stimuli, but to varying degrees. Excluding the final test interval (134 hr after fish were introduced into tank), differences in response to dark and light backgrounds between the two species were correlated to differences in swimming activity rather than speciation. The greater preference for black by the rainbow trout at the conclusion of the experiments suggests that the brown trout habituated sooner after the fright stimulus. Butler and Hawthorne (1969) and Lewis (1969) attribute relative differences in the fright response of brown and rainbow trout, specifically the use of overhead cover, to speciation differences.

Fright stimuli cause the trout to gather over the black during which time spatial movement is minimal. As the fish habituate or recover from the fright stimuli (increase in light intensity), the tendency towards random movement about the tank increases until the preference for dark areas becomes insignificant. Previous observations on rainbow trout (Kwain and MacCrimmon 1967) have not only shown a positive relationship between light intensity and swimming activity, but revealed that at a higher intensity of 200 1x swimming activity may become so pronounced that the selection of black background does not occur at all or, as observed in our experiments, occurs for only a short period of time after the fright stimulus. Under these conditions the fish tend to respond more as a group and occasionally school. This group activity, similar to the selection of black background areas, is interpreted as being a security reaction, as Breder (1967) suggests that occasional schooling species school as a result of environmental change or fright. In our experiments the sudden increase in light intensity provided the fright stimulus causing immediate selection of black background followed shortly after by group activity sometimes in the form of schooling.

By singling out only two behavioral features (background selection and swimming activity), it has been demonstrated that the responses of trout to imposed fright stimuli are predictable only under set controlled conditions and vary with different environmental conditions. Ecological factors other than light intensity and water flow from the complex aquatic environment undoubtedly significantly affect the behavior patterns of trout. The importance of these factors in influencing trout behavior can best be identified through a combination of laboratory and field investigations.

Acknowledgments — Financial support for this research was provided by operating grants of the National Research Council and the Conjoint Committee of the

Ontario Department of Lands and Forests to which we express our appreciation.

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Determination of Fat Content in Fish with a Nontoxic, Noninflammable Solvent

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KORN, S., AND D. MACEDO. 1973. Determination of fat content in fish with a nontoxic, noninflammable solvent. J. Fish. Res. Board Can. 30: 1880–1881.

An inexpensive method to determine the fat content in fish using a nontoxic, noninflammable solvent is described. A preweighed, dry, ground fish sample is put in a chromatography column with anhydrous sodium sulfate. One hundred milliliters of monofluorotrichloromethane (MF Freon, refrigerant-11) is poured through the column and the effluent collected in a preweighed beaker. After evaporation of the solvent on a hot plate and cooling in a desiccator, the fat is weighed and fat content calculated. Calculations for samples from two species were similar to those obtained by Association of Official Agricultural Chemists fat extractor method. The column method compares favorably with the fat extractor concerning cost and time.

KORN, S., AND D. MACEDO. 1973. Determination of fat content in fish with a nontoxic, noninflammable solvent. J. Fish. Res. Board Can. 30: 1880–1881.

Les auteurs décrivent une méthode peu dispendieuse permettant de déterminer la teneur en gras du poisson à l'aide d'un solvant non toxique et ininflammable. Un échantillon de poisson, préalablement pesé, séché et moulu, est placé dans une colonne à chromatographie avec du Na_2SO_4 anhydre. On verse dans la colonne 100 ml de monofluorotrichlorométhane (MF Freon, réfrigérant-11), et on recueille l'effluent dans un becher préalablement pesé. Après évaporation du solvant sur une plaque chauffante et refroidissement dans un dessicateur, on pèse la graisse et on calcule la teneur en gras. Les auteurs comparent la méthode de la colonne avec celle de l'extracteur des graisses donnée par l'Association of Official Agricultural Chemists et arrivent à des résultats semblables. Sous le rapport à la fois du coût et du temps requis, la méthode de la colonne se compare favorablement avec celle de l'extracteur des graisses.

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THIS report describes an inexpensive column extraction procedure for determining fat content in fishes which utilizes a nontoxic and noninflammable solvent. Toxic, inflammable solvents such as ether, chloroform, and benzene are used in other methods: mainly by extraction by Soxhlet-type apparatus (Goldfisch Fat Extractor[1], Horowitz 1965) and shaking the ground sample with a solvent (Folch et al. 1951; Bligh and Dyer 1959).

Fish samples are dried at 70 C for 96 hr and reduced to a coarse granular consistency by repeated cutting with scissors or by electric blending. The dried samples and the 150-ml fat collection beakers are stored in a desiccator for use.

Chromatography columns (20 × 400 mm) with a size 2 teflon stopcock fused just below the fritted disc are prepared for extraction by inserting 20 g anhydrous sodium sulfate (Na_2SO_4) into the bottom of the column. A weighed dry fish sample mixed with 40 g Na_2SO_4 is poured into the column, followed by another 20 g of Na_2SO_4. One hundred milliliters of monofluorotrichloromethane (MF Freon, refrigerant-11) is poured into the column and the effluent collected with dry preweighed 150-ml beakers. Just after the effluent starts passing through the column, the valve is closed for a 1-hr retention period. This stops the flow and allows for a soak period. The extract is collected and the contents are concentrated on a hot plate (40–50 C) in a fume hood to near dryness (30–60 min). The beakers are then dried for 1 hr in a 70 C oven and cooled in a desiccator. After reweighing the beakers, the fat weight and the fat concentration are calculated.

To compare this method with an established procedure, dried fish were blended and divided into 47 2-g samples (striped bass *Morone saxatilis*) and 35 4-g samples (Pacific herring, *Clupea harengus pallasi*). Half of the samples (six per trial) were run on a Labconco–Goldfish fat extraction apparatus using the A.O.A.C. method (Horowitz 1965). The other half (five to six per trial) were run simultaneously using the described method.

Two way analysis of variance of the data showed that the dried fish did not change in fat content over the test period ($P \leq 0.05$). This allowed us to combine values from different trials to compare results. Similar analysis also showed that results from the column method did not differ from the soxhlet procedure with 2- and 4-g samples ($P \leq 0.05$).

The percents fat obtained with the two methods were:

Method	Sample weight (*g*)	%Fat
Goldfisch fat extraction		
Striped bass (24)[a]	2.38±0.34[b]	18.2±0.34
Pacific herring (18)	4	7.84±0.20
Column fat extraction		
Striped bass (23)	2	18.1±0.64
Pacific herring (17)	4	7.87±0.17

[a] Number of fish.
[b] Mean and one standard error.

The column method compares favorably with other methods concerning labor and expense. It takes 3–4 hr from start to finish as compared with 6–7 hr for the Goldfisch apparatus and 24 hr for Folch's method. Cost for the column method is about $100 to set up equipment to run six samples simultaneously, and for the fat extractor about $990 plus the cost of extraction solvents. The column method also has applications in extracting fat from other samples, e.g. wet fish tissues, food stuffs, and mammalian tissue (Hesselberg and Johnson 1972).

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[1] Reference to trade names in this paper does not imply endorsement of commercial products.

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Changes in Periphytic Algae Following Bicarbonate Additions to a Small Stream

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Dickman, M. 1973. Changes in periphytic algae following bicarbonate additions to a small stream. J. Fish. Res. Board Can. 30: 1882–1884.

Additions of less than 50 mg/liter sodium bicarbonate significantly increased algal standing crop on glass slides exposed in the treated portion of a small stream during a 2-month period. Filamentous green algae dominated the periphyton community of both bicarbonate treated and control slides when the study was terminated after 63 days. A slight shift in species composition toward the Cyanophycea on the bicarbonate treated slides was also noted.

Dickman, M. 1973. *Changes in periphytic algae following bicarbonate additions to a small stream.* J. Fish. Res. Board Can. 30: 1882–1884.

L'addition de moins de 50 mg/litre de bicarbonate de sodium résulte en une augmentation significative de la biomasse d'algues sur des lames de verre exposées dans la portion traitée d'un petit cours d'eau, sur une période de 2 mois. A la fin de l'expérience, soit après 63 jours, les algues vertes filalmenteuses dominent dans la communauté périphytique, tant sur les lames traitées au bicarbonate que sur les lames témoins. On note un léger déplacement vers les Cyanophycea dans la composition des espèces sur les lames traitées au bicarbonate.

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Under certain conditions either phosphorous nitrogen or carbon exerts the greatest effect on algal growth. This point is particularly significant in view of the controversy over the effects of various detergent phosphate substitutes. The effects of bicarbonate as an agent of eutrophication is often overlooked (King 1970), although many researchers in the forties and fifties reported a direct correlation between biological productivity and alkalinity (Waters 1957). Changes in the productivity and species composition of attached algae following bicarbonate addition has never been studied under field conditions. Because a number of detergent manufacturers are contemplating substituting carbonate or bicarbonate derivitives for detergent phosphate a study of the effects of bicarbonate on attached algae in a small stream was undertaken.

Methods — The test stream was located at the outlet of Holly Lake (76°, 05′W; 54°, 35′N) in Gatineau Park, Quebec. During the course of this study (May 21–July 23, 1971) water flow velocities ranged from 8 to 17 gal/min (0.51–1.07 liter/min). Midstream depths varied from 0.7 to 1.5 m.

Two sets of glass microscope slides were numbered and placed in slide racks constructued of clear plastic (Dickman 1969). These were next mounted on wooden platforms (Fig. 1), anchored in the stream at 0.5 m depth. The two platforms were placed side-by-side thereby reducing the possibility of their being differentially affected by any differences in stream characteristics.

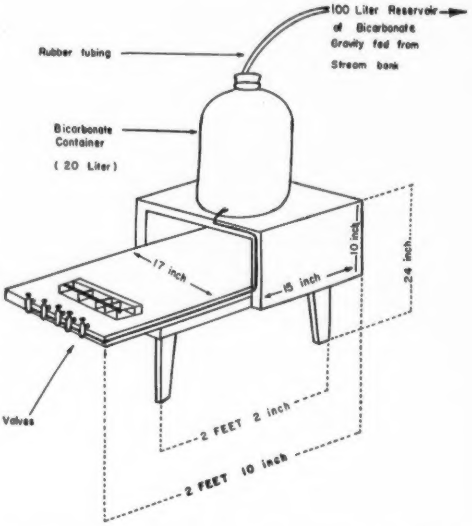

Fig. 1. Slide platform, slide rack, spigots, and 20-liter subreservoir.

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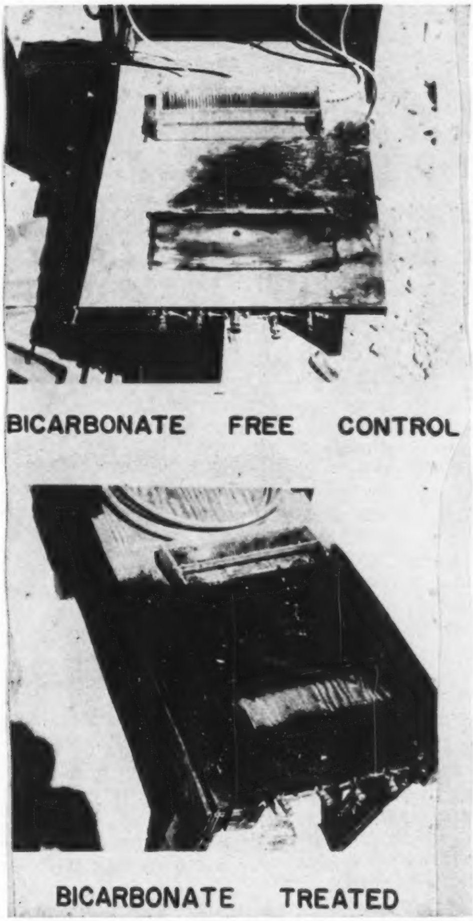
BICARBONATE FREE CONTROL
BICARBONATE TREATED

FIG. 2. Platforms following removal from the stream after 63 days. The dark felty material obscuring the grain of the wood is comprised largely of filamentous green algae. The slide rack was removed from its original position and placed at the rear of the platform for the photograph.

Dickman — J. Fish. Res. Board Can.

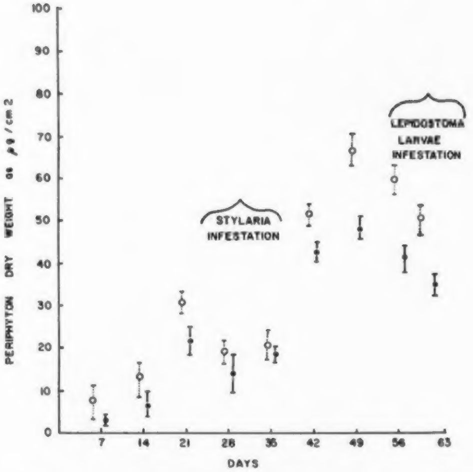

FIG. 3. Changes in periphyton dry weight on slides exposed over a 63-day period from May 21 to July 25, 1970. Vertical lines represent two standard deviations about the mean, N = 5.

This same proximity increased the chance of contamination of the control. Biweekly checks of the water in samples taken from between the slides of the control platform failed to show any elevated conductivity (i.e. conductivity was identical to the untreated water above the platforms) while conductivity below the treated platform was significantly higher due to the bicarbonate additions.

Two sets of five nozzles, located at the upstream end of each platform, irrigated the slides. The water was fed to the nozzles via plastic hoses from two 100-liter reservoirs; one filled with stream water (control), the other identical reservoir (treated) contained a 22.7 g/liter sodium bicarbonate ($NaHCO_3$) solution which was made with water from the same stream. Both reservoirs were refilled twice a week. The water was gravity fed to a second smaller reservoir (20-liter polyethylene container) and then to five spigots. After passing through the spigots it mixed with the river water as it passed over the slides. The bicarbonate concentration of water collected from between and below the slides was adjusted to 45 mg/liter by opening or closing the spigot valves which controlled the flow rate from the reservoir. A concentration of 45 mg/liter was chosen as it was 2½ times the bicarbonate concentration in the experimental stream but remained well within the natural range of bicarbonate variation found within the lakes and rivers of Gatineau Park (12–87 mg/liter). Bicarbonate concentrations were determined at the start and end of the study using standard methods (A.P.H.A. 1965) and Hach chemicals. During the study period the bicarbonate levels were monitored indirectly by using a Beckman RA-2A conductivity meter as the increase in conductivity of treated water was shown to be proportional to the increase in bicarbonate concentration added to this water.

After bicarbonate addition, *p*H increased from 6.8 to 7.0 in the water perfusing the treated slides. No attempt to buffer the perfusing solution was made for fear that the buffer would introduce changes in itself. Significant differences in periphyton growth might have been due more to differences in *p*H or the additional sodium cation introduced with the bicarbonate solution. We feel, however, that such conclusions are unlikely as our induced increase in *p*H did not significantly raise the level above its natural variation in the stream (6.4–7.0). Sodium is a micronutrient and was already at sufficient concentration in the river water (0.46 mg/liter) to meet normal algal growth requirements. Thus, increased algal growth would be more likely attributable to the bicarbonate (HCO_3), a macronutrient, at 17.5 mg/liter in the stream and to the free CO_2 (25.2 ± 0.6 mg/liter).

Flow interruptions were rare and we are sure that for at least 50 of the 63 days of the experiment the slides were being continuously perfused with solutions from their respective reservoirs.

Each week five slides were removed from each rack for standing crop and periphyton enumeration. The periphyton was scraped from one side of each slide, placed on a preweighed Whatman #1 filter, dried for 24 hr at 60 C, and reweighed. The periphyton was enumerated by counting the organisms of each taxa from a 1-cm^2 subsample removed from the unscraped side of each slide. Ninety randomly selected fields, 30 under oil immersion (1500×), 30 under high dry (600×), and 30 under medium power (150×) were chosen.

The Inland Waters Branch of the Department of Environment Canada, conducted a series of analyses, during the summer of 1971, on an adjoining creek in the same watershed (personal communication) with the following mean values ± 2 SD:

Total calcium carbonate hardness	: 31.3±0.2 mg/liter
Dissolved calcium	: 11.9±0.3 mg/liter
Total carbonate	: 17.5±1.1 mg/liter
Dissolved oxygen	: approx 100% saturation
Total organic carbon	: 5.4±3.6 mg/liter
Dissolved carbon	: 5.1±2.1 mg/liter
Total kjeldahl nitrogen	: 0.4±0.2 mg/liter
Total NO_3-N	: 0.12±0.09 mg/liter
Total PO_4-P	: 0.041±0.025 mg/liter
*p*H	: 6.4 to 7.0 (mean:6.8)

In humid bog waters the organic acids there function as liquid ion exchangers replacing cations with hydrogen ions during the alkalinity titrations. Thus, it is likely that the carbonate–bicarbonate alkalinity results would be over estimated for these bog waters by as much as half an order of magnitude (personal communication).

Results and discussion—Some results of bicarbonate additions were indicated by comparing the amount of algal growth on the two platforms after the experiment had been terminated on July 23 (Fig. 2). The dark area on the bicarbonate-treated platform as well as on the slides was comprised of a dense mat of filamentous green algae, composed principally of *Mougeotia* sp., *Oeodogonium* sp., *Zygnema* sp., and *Bulbochaete* sp. and to a lesser extent, *Spirogyra* sp. Intertangled in these strands were the dominant diatoms, *Nitzschia subtilis* (Kutz.) Grun., *Achnanthes minutissima* Kutz., *Navicula radiosa* Kutz., *Neidium affine* (Ehr.) Pfitz, *Gomphonema acuminatum* Ehr., *Stephanodiscus astraea* (Ehr.) Grun., *Fragilaria rhomboides* (Ehr.) De Toni, *Synedra ulna* (Nitzsch.), and *Pinnularia nodosa* (Ehr.) W.Sm. In addition to the diatoms, *Sphaerocystis* sp., *Ankistrodesmus falcatus* (Croda) Ralfs, *Cosmarium* spp., *Euastrum* spp., *Anabaena* spp., *Aphanocapsa* spp. *Chroococcus prescottii* Drouet and Daily, *Gloeotrichia* spp., and *Microcystis* spp. were common to abundant. Algal species composition on the control slides and platform was not drastically different from the treated slides apart from a slightly lower density of some cyanophyta species. The presence of more *Aphanocapsa*, *Chroococcus*, and *Gloeotrichia* on the treated slides supports the contention of Jackson (1964) that these species are favored at elevated bicarbonate concentrations. Shapiro (1973) also noted a selection of blue-green algae at high *p*H. However, the *p*H levels described by Jackson (8.4 and above) never occurred in this study.

Periphyton biomass increased continuously for the first 3 weeks and this increase was slightly more rapid on the treated slides (Fig. 3). After the 4th week, biomass suddenly declined due to a dense "infestation" of the oligochaete, *Stylaria lacustris* which often contained algal cells, largely diatoms, in its gut. This annelid did not appear to ingest filamentous algae, however, and as the filamentous green algae began to dominate the community on the slides, the number of *Stylaria* decreased. By the end of the 2nd month a trichopteran larva, *Lepidostoma* sp., became abundant and algal standing crop again sharply dropped (Fig. 3). It dropped more precipitously on the treated slides during these infestations due to higher invertebrate densities there. Nevertheless, statistically significant differness ($P = .05$) remained between the treated and control slides at the conclusion of the experiment (Fig. 3).

Thus, our results indicated that relatively small increases of less than 50 mg/liter bicarbonate in a small bog-lake's outlet stream was sufficient to stimulate a dense algal standing crop. With the exception of a slightly denser growth of cyanophyta colonizing the treated samples, species composition did not differ appreciably between treated and control slides. The fact that *p*H remained relatively unchanged from that of the control (7.0 vs. 6.8) throughout the experiment may account for why the massive changes in species composition observed by Shapiro (1973) were not noted here.

Acknowledgments — The interest of Drs M. Gochnauer and D. J. Kushner in this project and their constructive criticism is most appreciated. Mr A. Boudria offered invaluable technical assistance throughout the study by monitoring the field equipment and drafting the figures. The National Capital Commission kindly permitted the use of the study stream and the National Research Council of Canada supported the study under Grant No. A 6128. I am grateful to all of the above for their support.

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Contributions to the Biology of the Bering Cisco (*Coregonus lauretttae*) in Alaska

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ALT, K. T. 1973. Contributions to the biology of the Bering cisco (*Coregonus laurettae*) in Alaska. J. Fish. Res. Board Can. 30: 1885–1888.

Taxonomic and biological data are presented on Bering cisco, *Coregonus laurettae* Bean, from the South Fork of the Kuskokwim River; Hess Creek and the Porcupine River in the Yukon System; and the Koyuk River and Port Clarence–Grantley Harbor area of western Alaska. Gill raker counts ranged from 31–40 with means of 33.8–36.6, those on the lower arch 18–24 with means of 20.4–23.6.

Potential spawners were found 1610 km up the Yukon River in mid-June and 262 were taken at the mouth of Hess Creek in the Yukon River 1270 km upstream from the mouth June 10–14, 1972.

Bering cisco from Hess Creek grow faster than cisco from Port Clarence–Grantley Harbor, reaching a maximum length of 480 mm and 8 years of age. Growth rates for males and females are similar.

ALT, K. T. 1973. Contributions to the biology of the Bering cisco (*Coregonus laurettae*) in Alaska. J. Fish. Res. Board Can. 30: 1885–1888.

L'auteur présente des données sur la taxonomie et la biologie du cisco de l'Alaska, *Coregonus laurettae* Bean, de la branche Sud de la rivière Kuskokwim; du ruisseau Hess et de la rivière Porcupine dans le régime du Yukon; et de la rivière Koyuk et de la région Port Clarence–Grantley Harbor de l'Alaska occidental. Le nombre de branchicténies varie de 31 à 40, avec moyennes de 33.8 à 33.6, celles de l'arc inférieur allant de 18 à 24, avec moyennes de 20.4 à 23.6.

Des géniteurs en puissance ont été trouvés à 1610 km en amont dans le fleuve Yukon à la mi-juin, et 262 ont été capturés à l'embouchure du ruisseau Hess dans le fleuve Yukon à 1270 km en amont de l'embouchure de ce dernier les 10–14 juin 1972.

Le cisco de l'Alaska du ruisseau Hess croît plus rapidement que celui de Port Clarence–Grantley Harbor et atteint une longueur de 480 mm et un âge de 8 ans. Mâles et femelles croissent au même rythme.

Received May 22, 1973

THIS note presents the first biological data on the Bering cisco, *Coregonus laurettae* Bean. It had always been combined with the Arctic cisco, *C. autumnalis*, until McPhail (1966) established *C. laurettae* as a valid species. It is distributed from the Gulf of Alaska to Oliktok near the Colville River and probably also in the Chukotsk and Kamchatka regions of Siberia (McPhail and Lindsey 1970).

At present, it is little utilized with the exception of small numbers taken for subsistence use by gillnet and fishwheel.

Materials and methods — Bering cisco were taken in the course of inconnu, *Stenodus leucichthys*, and whitefish, *Coregonus* sp., movement and distribution studies in 1971 and 1972. Variable mesh gillnets, with five 7.5 m panels of ½–2½-inch bar mesh, and native fishwheels were used to collect cisco.

Fish were taken 3 km up the South Fork of the Kuskokwim River, the Yukon River from the Nowitna River mouth to Dall River mouth, the Porcupine River, the Koyuk River in Norton Sound, and the Port Clarence–Grantley Harbor and Imuruk Basin area near Teller (Fig. 1).

Gill raker counts, including rudiments, were made in the field on the excised first left arch. Age determinations were made using the scale method.

Taxonomy — The Bering and Arctic cisco are similar in appearance, both having a terminal mouth and immaculate pectoral and pelvic fins. The Bering cisco has significantly fewer gill rakers ($\bar{x}$ = 33.8–36.6) than the Arctic cisco ($\bar{x}$ = 42.1 from Colville River, *n* = 10; Alt and Kogl 1973). Gill raker counts of *C. laurettae* from Bering Sea drainages are presented in Table 1 and range from

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31–40 total count and 18–24 on the lower arch. The highest counts are from the Koyuk River ($\bar{x} = 23.6$ on the lower arch) and the lowest counts are from Port Clarence–Grantley Harbor fish ($\bar{x} = 20.4$ on the lower arch).

Movements — Bering cisco are generally more abundant near the coast. During limnological investigations of the Port Clarence, Grantley Harbor, and Imuruk Basin area in 1971 and 1972, 21 Bering cisco (seven net nights) were taken in Port Clarence and Grantley Harbor where the salinity ranged from 27‰ to 31‰. Only four were taken in the Imuruk Basin area (35 net nights) where salinity was 1–4‰.

Ten Bering cisco, all potential spawners containing large eggs, were taken in the South Fork of the Kuskokwim River, 840 km from the ocean, in late July during 2 net nights of fishing. No cisco were taken during extensive test netting in the area of the Holitna River in June and July, nor were any taken during test netting of other upper Kuskokwim tributaries in September. The spawning run was not followed further. No spawning checks were found on the scales of these fish.

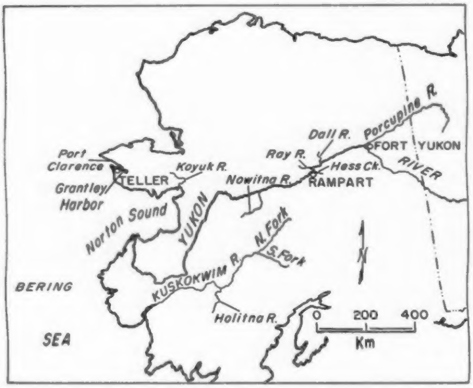

FIG. 1. Bering cisco (*Coregonus laurettae*) study areas in Alaska.

Bering cisco are present at the mouths of middle Yukon River tributary streams early in the summer (Nowitna River — June 7, Porcupine River — June 17) and numbers fluctuate (Table 2). This is a spawning migration and all fish examined had large eggs. During June, 1972, when 273 cisco were taken in the lower 500 m of Hess Creek (40 km above Rampart); a gillnet was set 3.2 km up Hess Creek, but no Bering cisco were taken. Test netting at the mouths of Hess Creek, Ray and Dall rivers July 8–22 took only 12 Bering cisco (all mature) and again the net 3.2 km upstream in Hess Creek contained none. The lower 110 km of Hess Creek was floated August 21–23 and no cisco were noted. Nets at the mouth of Hess Creek at this time took only one Bering cisco.

At Rampart, a fishwheel operating in the Yukon River from August 25 to October 1 took 180 Bering cisco. During the peak of this run, September 4–8, up to 18 were taken per day. The run abruptly stopped on September 16. All fish had large eggs and would probably spawn that fall. The spawning grounds of these fish are still unknown. Some evidently spawn in the Yukon River system upstream of the mouth of the Porcupine River as a fishwheel at Fort Yukon took four to six cisco per day in late August.

The presence of Bering cisco in the lower Porcupine River 1610 km up from the mouth of the Yukon on June 17 suggests overwintering in the middle Yukon area or a very rapid upstream migration.

TABLE 1. Gill raker counts of Alaskan Bering cisco.

Area	n	Total count			Lower arch		
		Range	$\bar{x}$	SD	Range	$\bar{x}$	SD
Port Clarence– Grantley Harbor	21	31–36	33.8	1.50	18–23[a]	20.4	1.17
Koyuk River	7	34–40	36.6	2.07	21–24	23.6	0.97
Yukon River							
Hess Creek	24	33–37	35.5	1.28	20–24	22.0	0.95
Porcupine R.	8	33–37	34.4	1.36	21–23	21.6	0.72
South Fork of Kuskokwim R.	10	33–37	34.6	1.40	20–22	21.4	0.69

[a] $n = 18$

TABLE 2. Results of Bering cisco test netting, middle Yukon River, 1971 and 1972.

Date	Location	Net nights	No. caught	Fish/ net night
June 1–9, 1972	Nowitna River	18	2	0.1
June 10, 1972	Texas Creek	1	10	10.0
June 23, 1971	Minook Creek	1	10	10.0
June 10–14, 1972	Hess Creek	10	262	26.2
June 22, 1971	Hess Creek	2	65	32.5
June 26–27, 1972	Hess Creek	4	11	2.8
July 8–11, 1972	Hess Creek	8	8	1.0
July 20–22, 1972	Hess Creek	8	0	0.0
Aug. 21–22, 1972	Hess Creek	4	1	0.3
June 14–15, 1972	Ray River	4	18	4.5
June 21, 1971	Ray River	2	7	3.5
June 23, 1971	Ray River	2	25	12.5
June 24, 1971	Ray River	2	11	5.5
July 12–14, 1972	Ray River	4	4	1.0
July 18–19, 1972	Ray River	1	0	0.0
June 20, 1971	Dall River	2	1	0.5
July 15–17, 1972	Dall River	3	0	0.0
June 17, 1971	Porcupine River	2	3	1.5
June 17–23, 1972	Porcupine River	7	0	0.0
		Total	438	

Age and growth — Ninety-seven Hess Creek (56 males, 315–475 mm; 41 females, 335–480 mm) and 17 Port Clarence–Grantley Harbor (10 males, 235–340 mm; 7 females, 235–350 mm) Bering cisco were aged. The Hess Creek sample was selected to include fish of the entire length range captured.

The majority of Hess Creek males were age V and VI while females were age V, VI, and VII. The Port Clarence–Grantley Harbor fish were mainly immature fish of age III, IV, and VI. One age VII female was captured. Data were analyzed using the abbreviated Doolittle Method (Draper and Smith 1966) and indicated no significant difference between growth of males and females from Hess Creek ($\alpha > .1$) and Port Clarence–Grantley Harbor ($\alpha > .5$) at the 90% confidence level. Sexes were combined in the comparison of growth of Hess Creek Bering cisco and Port Clarence–Grantley Harbor fish (Fig. 2). Hess Creek fish grew faster tdan Port Clarence–Grantley Harbor fish (abbreviated Doolittle Method gave $\alpha < .001$).

No comparative Bering cisco age and growth data are available in the literature. Ten mature Bering cisco taken 3 km up the South Fork of the Kuskokwim in July (320–410 mm) were age III–VII and had age-length relationships similar to Hess Creek cisco. One male was age III, one female was age IV, and the remainder were age V or older.

Both male and female cisco from Hess Creek became mature at age IV. Only one male of age VIII was taken but five females of age VIII averaged 439 mm. No indication of retained eggs was noted in Hess Creek fish.

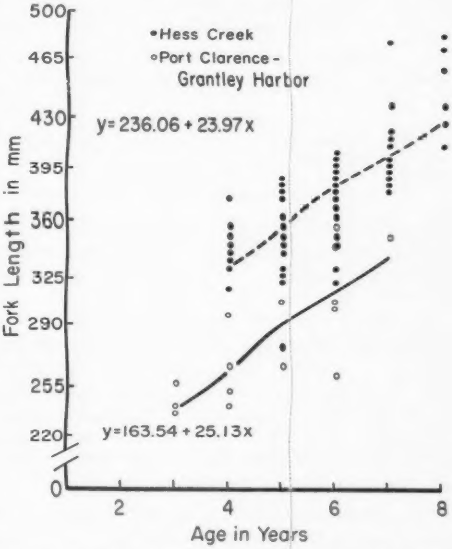

FIG. 2. Age–length relationship of Alaskan Bering cisco.

Faster growth of Kuskokwim and Yukon river fish is to be expected because of their longer growing season. Broad whitefish from these areas grew faster than broad whitefish from the Imuruk Basin–Grantley Harbor area near Teller (K. T. Alt unpublished data.)

Food habits — All the Bering cisco examined from the Yukon and Kuskokwim rivers (June through September) were potential spawners and had empty stomachs, a condition common to many species of whitefish in Alaska.

Limited data from the Port Clarence–Grantley Harbor and the Koyuk River indicated cisco were feeding on invertebrates and small fish.

Acknowledgments — This investigation was conducted with U.S. Federal Aid in Fish Restoration funds.

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The Slender Eelblenny, *Lumpenus fabricii*, a Southern Record in Nova Scotia Waters

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ROJO, A. 1973. The slender eelblenny, *Lumpenus fabricii*, a southern record in Nova Scotia waters. J. Fish. Res. Board Can. 30: 1888–1889.

Two specimens of *Lumpenus fabricii* (Valenciennes) were found in the coastal waters of Nova Scotia. Their capture represents the most southerly record of the species as well as the first record for the province of Nova Scotia.

ROJO, A. 1973. The slender eelblenny, *Lumpenus fabricii*, a southern record in Nova Scotia waters. J. Fish. Res. Board Can. 30: 1888–1889.

Deux spécimens de lompénie élancée, *Lumpenus fabricii*, ont été capturés dans les eaux côtières de la Nouvelle-Ecosse. Leur capture représente le record le plus méridional et le premier pour cette province.

Received August 1, 1972

DURING regular collections by ichthyology students, two specimens of the slender eelblenny were caught in coastal waters of Nova Scotia (Fig. 1).

The specimens, both female, were captured with a small seine net at low tide on September 18 and October 11, 1971 in the same locality, Marriott's Cove, at 44°33′N, 64°15′50″W, a long, narrow cove in Mahone Bay, Lunenburg Co. They were caught in daylight some 10 ft from shore in an eelgrass marsh area, 12 ft deep; the bottom sandy, with a few boulders. Water temperature was 60 F.

The Arctic waters of Eurasia and America have been given as the range of distribution for the species (Ehrenbaum-Helgoland 1950; Jensen 1944; Suvorov 1948; Shmidt 1950; Gordon and Backus 1957). Leim and Scott (1966) summarized data for Canadian specimens from Labrador, Ungava Bay, and Gulf of St. Lawrence. According to Dunbar and Hildebrand (1952) this species is Arctic–subarctic with a wide tolerance.

Some of the diagnostic characters that distinguish this blenny are: dorsal rays, 60–65; anal, 38–45; pectoral, 15–17; vertebrae 67–70.

The Nova Scotia specimens, measuring 220 and 230 mm, had the following counts: dorsal, 61 rays both; anal, 41 both; pectoral, 13 and 15, respectively, and 68 vertebrae each. Both specimens are deposited in the N.S. Museum, Halifax, numbers NSM 973-Z-698 and NSM 973-Z-699.

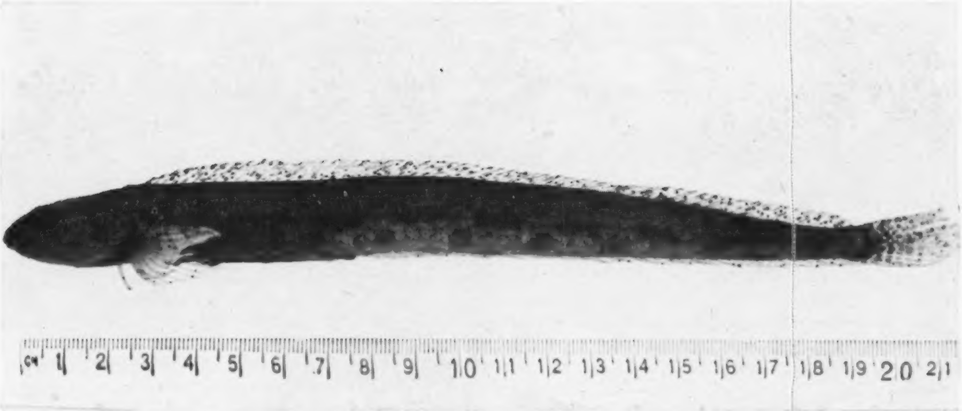

FIG. 1. The slender eelblenny, *Lumpenus fabricii*. (Photo R. E. Merrick)

These specimens have the lowest dorsal ray count (one less than the Labrador specimen). The number of pectoral and anal rays and the vertebral count are also in the lowest part of the reported range, in agreement with Gloger's rule that fish living in warm waters tend to have fewer meristic elements than those living in colder waters.

Jensen (1944) and Gordon and Backus (1957) gave the ratio of total length to body depth as varying from 11 to 15. The latter authors gave the ratio of total length to head length as 8:5. The same indices calculated from the Nova Scotia specimens were 13.8–14.4, and 7.9, respectively.

Acknowledgments — Thanks are extended to Dr W. B. Scott of the Royal Ontario Museum, Toronto, for his suggestions of references to this species; the students F. Kelly, R. Murdock, and W. Pierce, who collected the specimens; R. E. Merrick of the N.S. Museum in Halifax for the photograph of the fish, and Dr G. Hilliard, of Dalhousie University for the x-ray photographs from which vertebral counts were made.

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Open-Jaw Syndrome in Chinook Salmon (*Oncorhynchus tshawytscha*) at a Hatchery

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CROUCH, D. E., W. T. YASUTAKE, AND R. R. RUCKER. 1973. Open-jaw syndrome in chinook salmon (*Oncorhynchus tshawytscha*) at a hatchery. J. Fish. Res. Board Can. 30: 1890–1892.

Nearly 0.5% of the yearling spring chinook salmon (*Oncorhynchus tshawytscha*) at a national fish hatchery were observed with mouth agape, the condition occurring in two of 16 ponds. X-radiographs and histological preparations indicated that the articular bone of the lower jaw was malformed and dislocated dorsal and posterior to its normal point of attachment. The bone appeared to be embedded in the mandibular muscle and surrounded by an extensive fibrous tissue network. Genetic aberration, environmental interaction, and teratogenic substances are discussed as possible causes of the anomaly.

CROUCH, D. E., W. T. YASUTAKE, AND R. R. RUCKER. 1973. Open-jaw syndrome in chinook salmon (*Oncorhynchus tshawytscha*) at a hatchery. J. Fish. Res. Board Can. 30: 1890–1892.

Nous avons remarqué que près de 0.5% des saumons chinook (*Oncorhynchus tshawtyscha*) de printemps âgés d'un an, dans un établissement national de pisciculture, avaient la bouche grande ouverte, cette condition se rencontrant dans deux de 16 étangs. Des radiographies et des préparations histologiques démontrent que l'os articulaire de la mâchoire inférieure était difforme et décroché vers le haut et l'arrière de son point d'attache normal. L'os semblait enrobé dans le muscle mandibulaire et entouré d'un réseau volumineux de tissu fibreux. Nous examinons une aberration génétique, une interaction environnementale et diverses substances tératogènes comme causes possibles de cette anomalie.

Received July 4, 1973

THIS report describes an open-jaw condition (Fig. 1) observed in fingerling spring chinook salmon (*Oncorhynchus tshawytscha*), 8–10 cm in length, at the Eagle Creek National Fish Hatchery, Estacada, Oregon. Attention was given to anatomy of the condition, possible causes, and whether it might be transmissible.

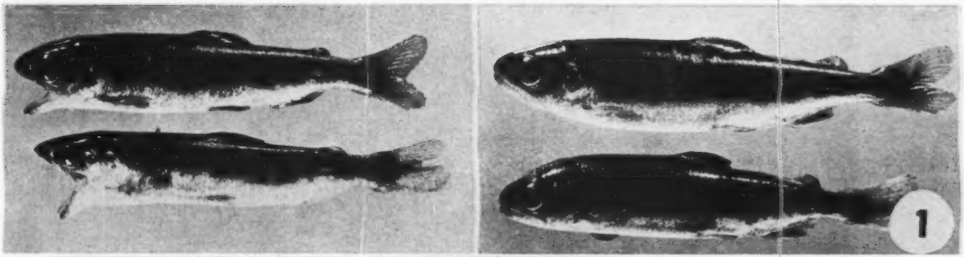
Mortalities exhibiting this condition were found mainly in two of 16 ponds containing approximately 1.2 million fish. The approximate losses for each of the two ponds in July, August, and September 1972 were 2000, 1500, and 1000, respectively. The average losses in the remaining ponds for the same 3 months were 600, 600, and 500 fish, respectively. The mortalities from the two ponds were mainly of fish afflicted with the open-jaw syndrome (OJS), while relatively few of the losses from the other 14 ponds were associated with the abnormality. Steelhead (*Salmo gairdneri*) held in adjacent ponds were not affected by the open jaw condition.

Printed in Canada (J3091)

The eggs of the spring chinook salmon were collected in September and October 1971 at the Eagle Creek hatchery. After hatching, 480,000 fry from the eggs collected in October were transferred to the Little White Salmon National Fish Hatchery, Cook, Washington; none of these fish exhibited the open-jaw syndrome.

There have been undocumented accounts of "gapers" occurring at other locations. Dr K. Bonham (personal communication) mentioned seeing fish with this condition for several years among chinook fry at the University of Washington, College of Fisheries. Two-year-old rainbow trout were similarly affected in an Oregon State fish hatchery (B. Earp personal communication). This condition was also observed in 18-month-old brown trout (*S. trutta*) at a California fish hatchery (R. J. Toth personal communication). There have been several other unpublished reports.

Materials and methods — Samples of OJS fish were tested for the presence of virus using standard tissue culture techniques. Bacterial examination was ac-



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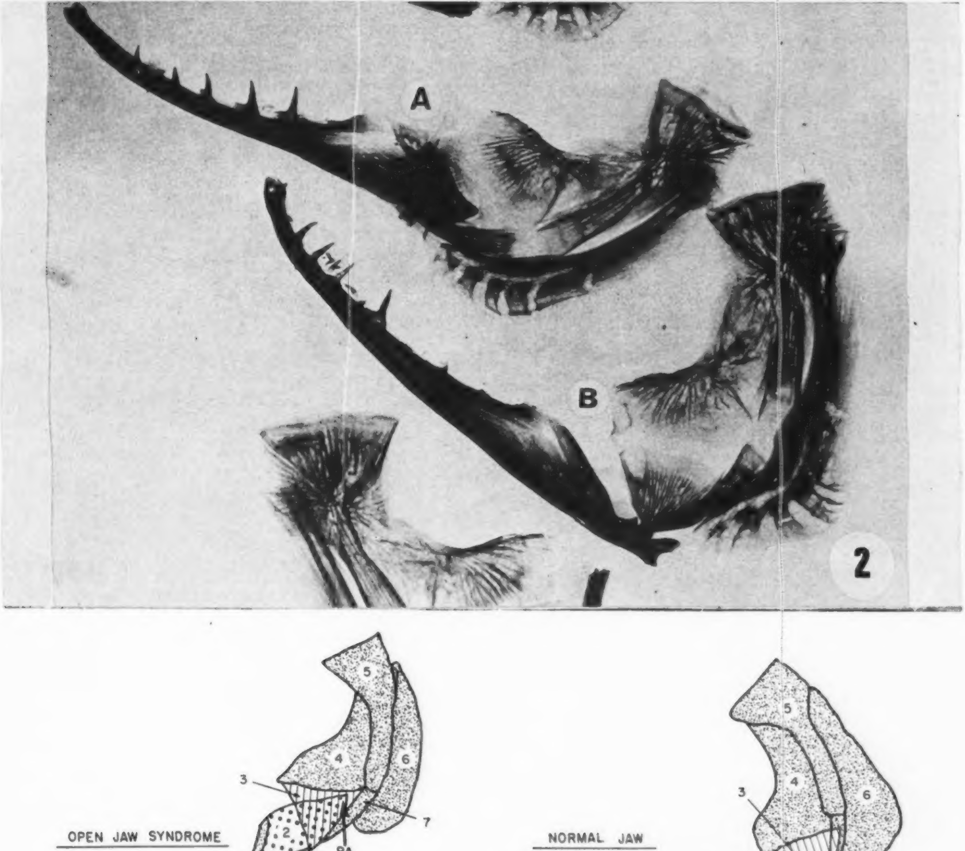

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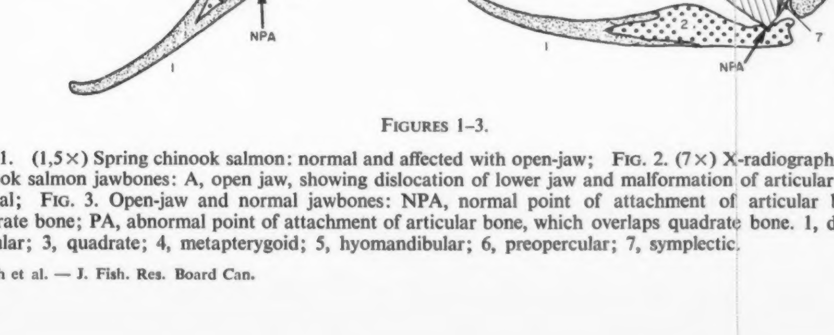

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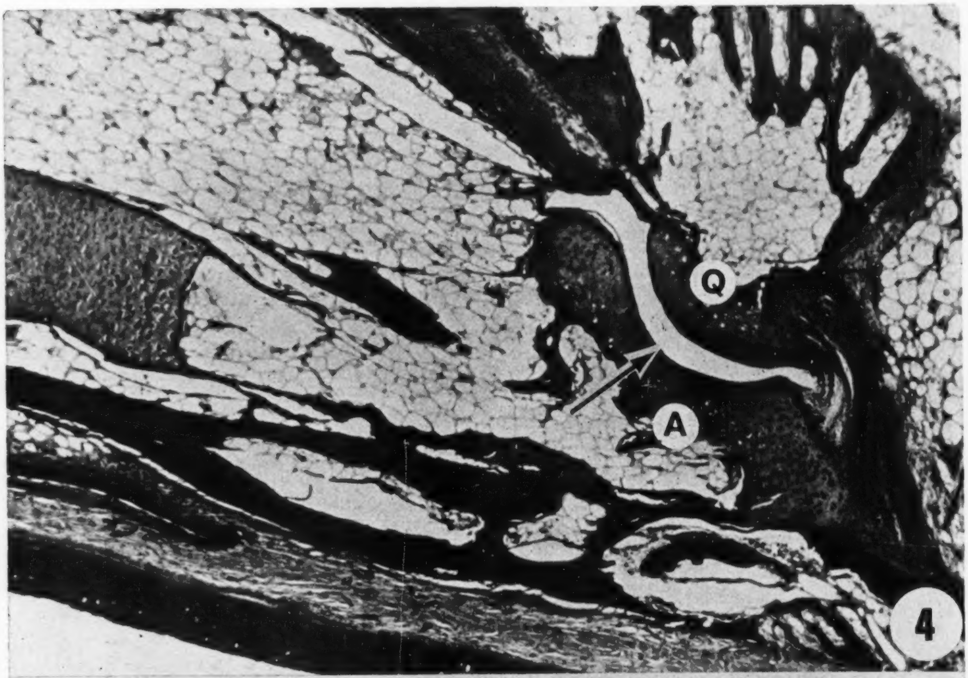
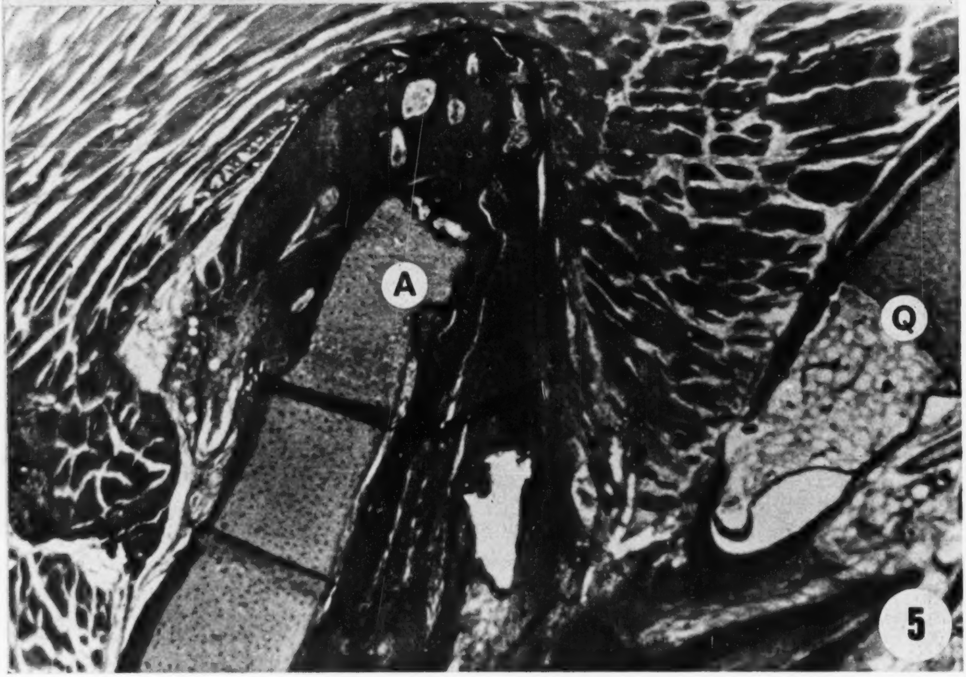
FIGURES 1–3.

FIG. 1. (1,5×) Spring chinook salmon: normal and affected with open-jaw; FIG. 2. (7×) X-radiograph of spring chinook salmon jawbones: A, open jaw, showing dislocation of lower jaw and malformation of articular bone; B, normal; FIG. 3. Open-jaw and normal jawbones: NPA, normal point of attachment of articular bone with quadrate bone; PA, abnormal point of attachment of articular bone, which overlaps quadrate bone. 1, dentary; 2, articular; 3, quadrate; 4, metapterygoid; 5, hyomandibular; 6, preopercular; 7, symplectic.





FIGURES 4–5.

FIG. 4. (126×) Articular–quadrate joint in normal spring chinook salmon: A, articular bone; Q, quadrate bone. Arrow shows area of articulation. FIG. 5. (117×) Open-jaw in spring chinook salmon showing malformation and displacement of articular bone. Note the articular bone (A) embedded in the surrounding muscle. Q is a portion of the quadrate bone.

complished by gram stain and plate culture methods, and parasites were identified using wet mount preparations. Histological material was prepared for microscopic evaluation of the tissues.

Material from affected fish was ground with saline in a tissue grinder and inoculated into normal fingerling spring chinook salmon (0.1 ml/fish, intraperitoneally) to see if the condition could be reproduced. Groups containing 20 fish each were inoculated with one of the following preparations: 1) visceral homogenate, 2) ground material from the jaw area at the point where the lower jaw articulates with the skull, and 3) the above homogenates mixed and heated in boiling water 5 min. The fish were held for 2 months in partitioned troughs. A group of 20 normal fish and 20 uninoculated OJS fish were included to see if the condition could be passed from affected to nonaffected fish.

In another experiment, brain material from OJS fish was homogenized with saline and injected (0.1 ml/fish) into the neural canal of five anesthetized normal chinook yearlings. Five control fish were similarly treated with physiological saline.

Chemicals which relax and contract muscle were used to determine whether the condition was due to a nervous dysfunction. Five OJS fish were injected with 0.2 ml/fish of Prostigmin (0.5 mg/cm^3 neostigmin methylsulfate) intramuscularly. Five additional OJS fish were similarly injected with Flaxedil, (20 mg/cm^3 gallamine triethidide). Prostigmin increases muscle tension and therefore the muscle contraction caused by the drug should close the jaw. Flaxedil blocks nervous activity to the muscles and the use of this substance should let the jaw relax and close by removing nervous stimulation to the muscles.

Affected and normal chinook salmon were dissected to delineate the anatomical differences in the jaws. The skull was defleshed as outlined by MacLean (1971). The bones were studied while wet and movable and then dried for later examination. Measurements of the lower jaw were made from the anterior portion of the dentary to the posterior portion of the articular bone. X-radiographs of whole fish and skeletons were made to define the structure and placement of the jaw bones.

Results and discussion — When the jaws of the OJS fish were closed manually the lower jaw appeared shorter than the maxilla. Measurements of the maxilla and the lower jaw of normal and OJS fish (10 fish each group) indicated that the lower jaw of the OJS fish was significantly shorter than the normal ($P < 0.05$). The means ($\pm$ standard deviation) were:

	Lower jaw (mm)	Maxilla (mm)
Normal	14.6 ± 0.7	12.4 ± 0.6
OJS	12.5 ± 0.64	11.9 ± 0.82

The dissections of the jaw showed a congestion of tissue in the area of the jaw articulation. Photoenlargements of the radiographs revealed a dislocation of the lower jaw and a malformation of the articular bone in the OJS fish (Fig. 2). The bone appeared to be shortened, increased in height at its dorsal curvature, and lacking the posterior portion, which includes the articulating surfaces. The lower jaw overlapped the quadrate, to which it is normally attached, and is located posterior and dorsal to this point (Fig. 3).

Histologically, the dislocation of the articular-quadrate joint was also apparent (Fig. 4 and 5). In the OJS fish the proximal end of the articular bone was embedded in the cephalic portion of the adductor mandibulae muscle. Others of this group showed that the muscle may have been simply pushed aside by the articular bone. Extensive fibrous connective tissue formation in the involved area may explain the chronic nature and the rigidity of the open mouth. The inflammatory response was minimal.

No bacterial or viral pathogens were isolated from the fish examined. Gill amoebae, *Costia* and *Hexamita* spp., were found on some of the fish; but there was no indication of a relationship between these parasites and the open-jaw condition. No evidence was obtained to suggest that the condition was laterally transmitted from fish to fish. The jaws of the OJS fish could be closed using manual pressure, but when the pressure was released the jaws flexed open to the original position. The drugs Prostigmin and Flaxedil had no effect on jaw closure and the jaws would not close when the fish were pithed or anesthetized.

Mortality in the OJS fish was most likely due to progressive starvation rather than infectious processes or toxicity. Although some fish having this condition were able to feed, as evidenced by food in the digestive tract, they were not able to take food as effectively as the normal fish and therefore probably succumbed to the pressures of competition.

No definite conclusion was drawn as to the specific cause of the OJS, however, there are some possibilities to be considered. Certain substances produce teratogenic anomalies in man and animals (Ferm 1972; Filippi 1967; and Smithells 1966). Some of these substances include heavy metals, endocrine preparations, cytotoxic agents, antibiotics, and sulfonamides. DeCew (1972) described a mandible teratogenicity in the progeny of brood spring chinook salmon treated prior to spawning with a mixture of procaine penicillin G, dihydrostreptomycin sulfate, and oxytetracycline HCl. None of the OJS brood fish were treated with chemicals except some malachite green prior to spawning.

Another possible explanation of the deformity might be the interaction of environmental and genetic factors on the developing eggs. Water quality and temperature would be the major environmental factors. The OJS eggs were incubated at 10 C to start and 7 C at hatching. Detailed water quality data are not available for the incubation period in 1971, however, the eggs were treated twice weekly with a malachite green flush at a concentration of 1.67 ppm.

The open-jaw syndrome might have been due to a chromosomal aberration transmitted to the offspring by genetic carriers of the trait.

Acknowledgments — We gratefully acknowledge the helpful suggestions and cooperation of R. Bigej, Eagle Creek National Fish Hatchery, Dr A. Wellander, University of Washington, and the staff of the Bacteriology and Virology sections of the Western Fish Disease Laboratory. We are especially grateful to Dr K. Bonham, University of Washington for the X-radiographs.

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Taxonomic Status of *Homoiotes palliata* Wilson, 1905 (Copepoda: Caligidae)

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Kabata, Z. 1973. Taxonomic status of *Homoiotes palliata* Wilson, 1905 (Copepoda: Caligidae). J. Fish. Res. Board Can. 30: 1892–1893.

Type material of *Homoiotes palliata* was examined and found to consist of a mixture of three species of *Lepeophtheirus* (*L. pravipes*, *L. breviventris*, and *L. bifidus*), all well established in the literature. It is suggested that *H. palliata* should be rejected as a taxon in the interest of nomenclatural stability. An approach to the International Commission on Zoological Nomenclature is being made, with this action in view.

Kabata, Z. 1973. Taxonomic status of *Homoiotes palliata* Wilson, 1905 (Copepoda: Caligidae). J. Fish. Res. Board Can. 30: 1892–1893.

Nous examinons le matériel type d'*Homoiotes palliata*. Il est constitué d'un mélange de trois expèces de *Lepeophtheirus* (*L. pravipes*, *L. breviventris* et *L. bifidus*), toutes bien établies dans la littérature. Nous suggérons l'élimination de *H. palliata* comme taxon, dans l'intérêt de la stabilité de la nomenclature. Nous nous adresserons à cette fin à l'International Commission on Zoological Nomenclature.

Received May 31, 1973

In one of his earliest publications on parasitic copepods of North American fishes, Wilson (1905) described a new caligid genus, *Homoiotes*, with the only species *H. palliata*. The description was based on one lot of specimens collected from the "blue cod," *Ophiodon elongatus*, at an unknown locality on an unknown date. The chief interest concerning the genus was in the fact that it provided a link between the two subfamilies of Caligidae, Caliginae, and Euryphorinae (the latter is now recognized as an independent family Euryphoridae). Conforming in all details to the diagnosis of Caliginae, it was shown by Wilson (1905, Pl. XXIX, fig. 378, 379) to have dorsal plates, developing from

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the fourth leg-bearing segment in immature individuals and gradually extending in a posterior direction. With age the plates were said to cover the entire genital complex and to fuse with it, and each other, so as to become difficult to detect.

Since 1905 several species of parasitic copepods have been described from *O. elongatus*. In view of economic value of this fish, some attention was given to its parasites by the staff of the Pacific Biological Station, Nanaimo. No finds of *H. palliata* were made. There are no literature records of occurrence of this species subsequent to Wilson's paper. Heegaard (1943) described another species of the genus, *Homoiotes bermudensis*, from the Atlantic but soon afterwards (Heegaard 1945) relegated it to synonymy with *Dentigryps curtus* Wilson, 1913.

It is difficult to accept the fact that a parasite of a fairly frequently investigated fish can be seen on one occasion and not be recorded again in more than 50 years. Curious about its identity, I examined Wilson's type material, kindly made available to me by Dr R. Cressey, Smithsonian Institution, Washington, D.C. The vial (original number W.75, accession no. USNM 42077) contained 82 specimens, most in a rather poor state of preservation. Examination showed that the specimens belonged to three species of the genus *Lepeophtheirus*, as indicated below.

	Mature ♀	Immature ♀	Mature ♂	Immature ♂
L. pravipes Wilson, 1912	26	2	4	–
L. breviventris Fraser, 1920	18	3	14	1
L. bifidus Fraser, 1920	5	–	1	–

Eight specimens, including mature and immature individuals, were impossible to identify.

The first two of the above species occur regularly on *O. elongatus*, *L. breviventris* being found mainly in the buccal cavity and *L. pravipes* on the outer surfaces of the fish. *L. bifidus* has so far been known only from flatfish hosts (Kabata 1973) and its presence in the same collection with the other two species cannot be explained.

Examining specimens in Wilson's material, one is at a loss to understand what prompted that notable carcinologist to describe dorsal plates which made the establishment of a new genus imperative. No specimens present in the vial show any structural features that can be interpreted as such plates, even at their most rudimentary. One can only hazard a guess that the so-called plates are artifacts produced by crumpling of the specimens in the fixative. This can be particularly true of the immature specimens with underdeveloped genital regions. In immature *Lepeophtheirus*, especially female, the genital complex is still in the process of expansion, its cuticle loose and its shape quite different from that of the adult genital region. Posterolateral corners are usually in the form of prominent lobes, often with folds and creases. The lobes diminish in size with age and in most species disappear altogether. During that process the fifth legs of the female are displaced from their apical position and brought onto the ventral surface of the genital complex, only rarely protruding beyond its margin. Comparison of Wilson's (1905) fig. 378 with Kabata's (1973) fig. 104 shows that the genital complex of the young of the alleged *H. palliata* and of *L. pravipes* are not dissimilar. The same is true of the corresponding part of *L. breviventris* (see Kabata 1973, fig. 20).

It seems clear, then, that *H. palliata* is a composite taxon. Because of Wilson's failure to designate a type specimen for it, only his fig. 365 and 366 link *H. palliata* with validly described species. The shape of the genital segment in these figures shows some similarities with the corresponding tagma of *L. pravipes*. The latter, however, has no dorsal plates at any known stage of development, so that its relationship with *H. palliata* remains uncertain.

The binomen *H. palliata* is older than any of the three species of *Lepeophtheirus* present in Wilson's material. Under the circumstances, two courses of action are open to us. One is to select a lectotype specimen from that material and to retain the specific name *palliata* as a senior synonym of the species to which it belongs. This would mean, however, altering the name of a species by now well established in the literature. In the interest of nomenclatural stability, I prefer, therefore, the second course, that of approaching the International Commission on Zoological Nomenclature with the view to placing the binomen *H. palliata* on the list of rejected names. This action is now being undertaken.

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Effects of Egg Concentrations of DDT and Dieldrin on Development in Winter Flounder (*Pseudopleuronectes americanus*)[1,2]

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SMITH, R. M., AND C. F. COLE. 1973. Effects of egg concentrations of DDT and dieldrin on development in winter flounder (*Pseudopleuronectes americanus*). J. Fish. Res. Board Can. 30: 1894–1898.

Abnormal gastrulation and a high incidence (mean = 39%) of vertebral deformities at hatching were encountered in developing eggs from winter flounder, *Pseudopleuronectes americanus*, experimentally exposed as adults to sublethal concentrations of DDT. Bone erosion and hemorrhaging at the vertebral junctures were often observed in conjunction with the vertebral deformities. No abnormal gastrulation and a lower incidence (mean <1%) of vertebral deformities without bone erosion and hemorrhaging were encountered in controls. DDT concentrations in the eggs ranged from 0.39 to 4.60 (mean = 2.42 ppm) compared to 0.11–0.57 ppm (mean = 0.22 ppm) in the eggs from control flounder. No observable effect on development was noted in eggs from adults exposed experimentally only to dieldrin except in two lots of eggs most of which were dead and necrotic at spawning and contained 1.74 and 1.21 ppm dieldrin. No direct effect on fertilization mortality was due to gamete concentrations of DDT and dieldrin and no residues of either insecticide were detected in the milt from exposed or control male flounder.

SMITH, R. M., AND C. F. COLE. 1973. Effects of egg concentrations of DDT and dieldrin on development in winter flounder (*Pseudopleuronectes americanus*). J. Fish. Res. Board Can. 30: 1894–1898.

On a observé une gastrulation anormale et une forte proportion (moyenne = 39%) de difformités vertébrales à l'éclosion chez des oeufs de plie rouge, *Pseudopleuronectes americanus*, qui avaient été exposés expérimentalement à l'état adulte à des concentrations sublétales de DDT. Souvent, les difformités de la colonne vertébrale sont accompagnées d'une érosion des os et d'hémorragies au point de jonction des vertèbres. Par ailleurs, les témoins ne montrent pas de gastrulation anormale et ont une plus faible occurrence (moyenne <1%) de difformités vertébrales, qui ne sont pas accompagnées d'érosion des os et d'hémorragies. La teneur en DDT des oeufs varie de 0.39 à 4.60 (moyenne = 2.42 ppm), comparativement à 0.11–0.57 ppm (moyenne = 0.22 ppm) dans les oeufs des plies témoins. Les oeufs d'adultes exposés expérimentalement à la dieldrine seulement semblent se développer normalement, à l'exception de deux lots constitués en grande partie d'oeufs qui étaient morts ou nécrosiques au moment de la fraie et qui contenaient 1.74 et 1.21 ppm de dieldrine. La mortalité à la fécondation ne peut être imputée directement aux concentrations de DDT et de dieldrine dans les gamètes, et on n'a pu déceler de résidus de l'un ou de l'autre insecticide dans la laitance de plies exposées, ni dans celle des poissons témoins.

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THE presence of DDT in eggs of several salmonid species has been associated with mortality at final yolk assimilation in developing fry (Burdick et al. 1964; Allison et al. 1964; Macek 1968; and Johnson and Pecor 1969). Macek (1968) also suggested that DDT residues in milt may have an added effect on fry mortality. In this study, residues of DDT and dieldrin were induced in eggs, but not milt, of winter flounder, *Pseudopleuronectes americanus*, and the effects of the various egg concentrations from fertilization to the time of expected exogenous feeding were investigated. To obtain test gametes, winter flounder were exposed experimentally to sublethal concentrations of the insecticides.

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[2] Based on a dissertation submitted by R.M.S. in partial fulfillment of the requirements for the degree of Doctor of Philosophy from the University of Massachusetts, 1971.

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Methods — Adult winter flounder were collected from Narragansett Bay during the fall before ripening and were held in 150-gal aquaria continuously supplied with filtered sea water. Ten individuals of each sex were placed in each of five test aquaria and subjected to the following treatments: 1 ppb DDT + 1 ppb dieldrin; 2 ppb DDT; 2 ppb dieldrin; an acetone control equal in amount to the highest concentration administered with an insecticide treatment; and an unaltered seawater control. Length of exposure, though variable, was based upon previous experimentation and generally was sufficient to duplicate gonad levels from a field study (Smith and Cole 1970). No factor was controlled except the level of residues in the gonads at the time of spawning. The insecticides were administered in acetone to the incoming water using 250-ml constant addition funnels (Kontes no. K634620). The DDT (1,1,1-trichloro-2,2-bis (*p*-chlorophenyl)ethane) used was technical grade (77.2% *p*, *p′* isomer), obtained from Nutritional Biochemicals Corporation. The dieldrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-*endo-exo*-5,8-dimethanonaphthalene) was analytical grade supplied by Shell Oil Company.

When the treated and control fish became ripe they were artificially spawned using methodology reported in Brice (1898). All male–female pairings involved gametes from flounder receiving the same insecticide treatment. Some females in each aquarium were discarded, upon becoming gravid, because of abrasive damage to the extent that the ovary on the blind side became exposed directly to the treated water. Fertilization was determined by the presence of membrane elevation, and the appearance of stress lines signifying the onset of the first cleavage.

Approximately 30,000 eggs from each spawning pair (24 pairs, Table 1) were cultured. The remaining eggs from the spawning were analyzed for insecticide residues. Approximately 2 ml of milt were also taken from each male for analysis. The eggs retained for culturing were held in specially constructed 2-liter funnel-bottom, flowing-water aquaria. At fertilization and on each day following, a sample of 200 eggs from each 30,000 fertilized-egg test lot was examined for percent mortality and incidence of abnormal development. At hatching, 9–12 days following fertilization, 200 prolarvae from each spawning pair were transferred to separate funnel-bottom aquaria and held. On every other day following hatching, two larvae from each test group were taken for microscopical examination. Any noticeably moribund larvae were also removed and examined. We were unable to provide an acceptable food for the larvae.

The analyses for residues of insecticides and their breakdown products in eggs (Table 1) and milt generally followed procedures in Smith and Cole (1970). Samples were extracted with acetonitrile, and partitioned into petroleum ether (Skellysolve F). Cleanup and partial separation were achieved with 6 and 15% ethyl ether in petroleum ether eleuents drawn over activated Florisil columns. Residues were determined and quantified on a Wilkens Aerograph Model 550 gas chromatograph equipped with a tritium foil electron capture detector. Most of the analyses were carried out using a column of 5% Dow 11 on Chromosorb W, 60/80 mesh. A second column of different polarity consisting of 50–10% DC-200 on Gas Chrom Q, and 50–12% QF-1 on Gas Chrom P, 100/120 mesh, was used as a cross reference. Partition coefficient values as described in Bowman and Beroza (1965) were employed in verification of identification. Operating conditions were: column temperature 190 C; injector temperature 230 C; detector temperature 200 C; carrier gas–pre-pure nitrogen at 60 ml/min. The recovery rates were between 88 and 91%. Data are not corrected. The possibility of a PCB interference with DDT detection and quantification was evaluated using silicic acid (Mallinckrodt) chromatography and was found to be nonexistent. Antibiotic treatments were not applied to the eggs, as such treatments may themselves be toxic (Oppenheimer 1955).

No DDT or dieldrin residues were detected in milt running from treated flounder. Our findings are not comparable with those of Macek (1968) who reported 0.02–0.64 ppm DDT in whole testes of male brook trout given sublethal doses in their food.

Results and discussion — In three spawnings involving eggs from treated adults, the percentage of fertilization differed markedly from that of the control matings (mean: 97.8%): 40% in eggs containing 4.60 ppm DDT and 0.01 ppm dieldrin; 12% in eggs containing 0.17 ppm DDT and 1.21 ppm dieldrin; and no fertilization in eggs with no detectable DDT but 1.74 ppm dieldrin (Table 1). In all three cases, many eggs were already dead within the ovaries, and gases were emitted during stripping. Macek (1968) reported no apparent adverse effect on fertilization of gametes from DDT-exposed adult brook trout.

The relations (Fig. 1) between DDT concentration in the eggs and mortality by the 4th day of development and at hatching ($r = 0.95$ and 0.80), respectively, indicated dose-dependent effects. Except for two examples of prefertilization mortality previously discussed, survival to hatching in eggs exposed to a dieldrin treatment only was similar to that in the controls.

We observed that gastrulation spans the 2nd through 4th days following fertilization in winter flounder. During this period, mortality in eggs with relatively high DDT concentrations (1.62 ppm or greater) was frequently associated with a failure to gastrulate. The cells at the perimeter of the blastula appeared unduly enlarged and occasionally detached from the underlying yolk. Death usually ensued within 24 hr. If abnormal development continued, instead of undergoing involution, as in normal gastrulation, the blastulae exogastrulated and development ceased.

At hatching, frequency of severe vertebral deformities was higher in larvae from DDT-treated than in those from untreated adults. Whole mounts of moribund newly-hatched larvae showed that

TABLE 1. Percent fertilization, estimated cumulative percent mortality during egg development, and percent of hatched larvae showing vertebral deformities in developing eggs and larvae from dosed and control winter flounder (*Pseudopleuronectes americanus*).

	Egg concentrations (*ppm*)				Mortality by specified day after spawning (%)												
Treatment	DDT	DDE	Dieldrin	% Fert.	1	2	3	4	5	6	7	8	9	10	11	12	% deformed
DDT	4.60	0.63	0.01	40	60	98	99	99	99	99	99+	99+	99+	99+	99+		77
+	3.08	0.28	<0.01	99+	25	25	74	74	72	80	–	77	82	88	97		40
Dieldrin	1.88	0.35	<0.01	99	30	34	–	45	70	74	74	80	88	93			28
	1.62	0.55	0.01	99+	2	2	2	34	39	–	31	29	40	40	40		37
	0.39	0.72	0.61	99+	5	5	10	32	50	48	50	70	86	90	91	92	40
DDT	3.70	0.07	0.00	99	5	2	73	–	83	79	84	91	98	98			44
	3.01	0.09	0.00	99	4	5	39	67	68	–	74	79	78	91			29
	2.39	0.10	0.00	80	19	27	79	77	83	96	96	95	94	99+			54
	1.15	0.40	0.00	99	33	29	24	44	50	–	52	52	51	55			2
Dieldrin	0.00	1.24	1.74	0	100												
	0.17	0.59	1.21	12	98	99+	100										
	0.50	0.17	0.02	99	5	32	30	43	43	40	44	47	49	48			< 1
	<0.01	0.78	<0.01	99	22	19	23	20	23	28	29	38	–	40			< 1
	0.18	0.16	<0.01	99	5	6	–	38	36	40	48	43	–	44			< 1
	0.62	0.14	<0.01	99	1	9	9	22	23	36	34	39	37	38			< 1
Acetone	0.27	0.13	<0.01	99	–	10	16	21	12	12	12	15	17	36			< 1
Control	0.27	0.11	0.00	90	12	40	13	35	34	44	43	51	49	53			< 1
	0.21	0.09	0.00	99	10	–	24	23	26	26	33	–	31	38	40		< 1
	0.18	0.57	0.00	99	10	10	22	26	25	33	34	41	41	39			< 1
	0.11	0.53	0.00	99	1	6	10	9	7	14	34	39	45	50			< 1
Control	0.57	0.51	0.00	99	2	4	19	–	38	36	51	51	60	59			< 1
	0.14	0.60	0.00	99	5	4	12	15	24	30	37	51	49	49			< 1
	0.14	0.57	0.00	98	10	16	13	19	23	–	38	39	40	38			< 1
	0.12	0.06	0.00	99	2	2	20	34	35	34	49	–	46	52			< 1

these deformities were frequently related to pockets of bone erosion at the vertebral junctures. Hemorrhaging was usually observed in the vicinity of the eroded pockets, but was also noted at vertebral junctures that did not show pockets of bone erosion. Although vertebral deformities were seen in all treatments, the percentage of deformed larvae (Table 1) tended to be dose-dependent. Only when DDT in the eggs equalled or exceeded 2.39 ppm was bone erosion with hemorrhaging at the vertebral junctures observed.

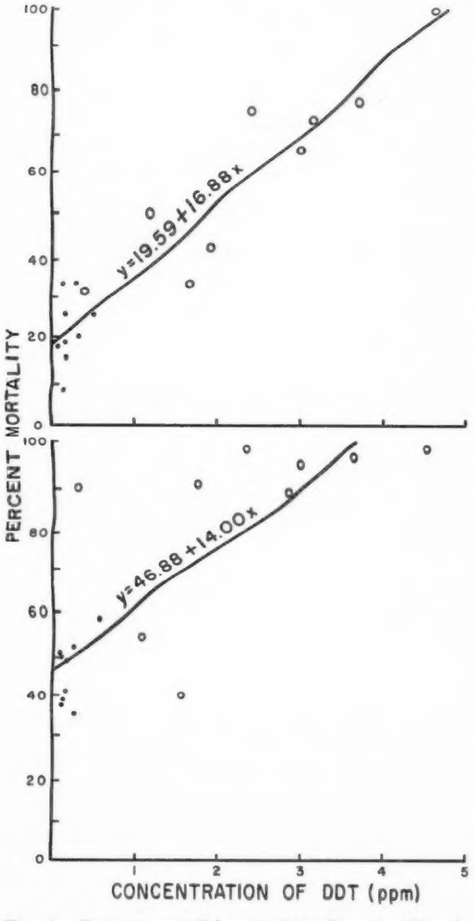

FIG. 1. Percent mortalities of winter flounder (*Pseudopleuronectes americanus*) eggs by the 4th day of development (*upper*) and at hatching (*lower*) in relation to concentration of DDT in the eggs (○, eggs from treated adult flounder; ●, eggs from control adult flounder).

All larvae, whether from dosed or control adults, died before acceptance of external foods. Dr G. Laurence (Narragansett Marine Gamefish Laboratory, Narragansett, R. I. personal communication) recently has had flounder larvae feed on natural food and reports that at 5 C they initiated feeding 7 days after hatching and that 50% were feeding by day 8. We were unable to initiate external feeding and deaths followed a characteristic sequence of tissue degeneration in both groups, resulting in total mortality between the 21st and 23rd days after hatching. This sequence began with a vacuolated fin fold, and was followed by necrosis of the fin fold and muscle tissue in the tail region. The necrosis advanced anteriorly from the tail and resulted in death when the body cavity was reached. Cessation of heartbeat was the criterion of death. There was no excessive loss in either treated or control larvae prior to and even well past the time of expected changeover to exogenous feeding. Thus we suspect that starvation was the cause of this mortality.

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Effect of a Reciprocal Photoperiod Regime on Standard Rate of Oxygen Consumption of Postsmolt Atlantic Salmon (*Salmo salar*)

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WITHEY, K. G., AND R. L. SAUNDERS. 1973. Effect of a reciprocal photoperiod regime on standard rate of oxygen consumption of postsmolt Atlantic salmon (*Salmo salar*). J. Fish. Res. Board Can. 30: 1898–1900.

Postsmolt Atlantic salmon (*Salmo salar*) subjected to a reciprocal photoperiod regime (decreasing daylength from early March and increasing daylength from late June) had significantly lower standard rates of oxygen consumption than those subjected to a simulated natural photoperiod regime when both were tested in total darkness in sea water in late summer. A reduced metabolic level, as indicated by the low standard rate of oxygen consumption, in the test fish is consistent with earlier observations of reduced feeding and growth rates and food conversion efficiencies in similarly treated fish following transfer to sea water.

WITHEY, K. G., AND R. L. SAUNDERS. 1973. Effect of a reciprocal photoperiod regime on standard rate of oxygen consumption of postsmolt Atlantic salmon (*Salmo salar*). J. Fish. Res. Board Can. 30: 1898–1900.

Des saumons atlantiques (*Salmo salar*) soumis à une photopériode inverse (diminution de la longueur du jour au printemps) à partir du début de mars ont des taux de consommation d'oxygène nettement inférieurs à ceux qui sont exposés à une photopériode naturelle simulée (accroissement de la longueur du jour au printemps), lors d'essais des deux groupes, en pleine obscurité et dans de l'eau de mer, à la fin de l'été. Cet abaissement du niveau métabolique, reflété par un faible taux standard de consommation d'oxygène chez les poissons exposés à une photopériode inverse, s'accorde avec des observations antérieures qui ont démontré un ralentissement de l'alimentation et de la croissance, et une diminution de l'efficacité de conversion des aliments chez des poissons qui avaient été traités de la même façon et transférés en eau salée.

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HOAR (1965) gives evidence that the smolting process in salmonids is triggered by changing photoperiod. Saunders and Henderson (1970) showed that smolting Atlantic salmon (*Salmo salar*) subjected to decreasing daylength from early March developed, during April and May while they were in fresh water, a higher condition factor than fish subjected to a simulated natural photoperiod regime. This was in contrast to the low condition factor which Hoar (1939) noted as characteristic of smolts. However, after the test fish were transferred in mid-May to sea water and subjected to increasing daylength from late June, they ate less, grew more slowly, and had lower efficiencies of food conversion than those under a simulated natural photoperiod regime. In the present study we examined the effects of the two photoperiod regimes on the standard rate of oxygen consumption in Atlantic salmon postsmolts and related the findings to previously described effects of the reciprocal photoperiod regime on feeding and growth rates.

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Materials and methods — Presmolt, hatchery-reared salmon were brought to St. Andrews in late December and held in fresh water through the winter at prevailing temperatures and simulated natural photoperiod. They were fed to satiation two or three times daily with Ewos (Astra Chemicals Ltd.) pelleted salmon food.

The fish were divided into two groups and introduced to experimental conditions on March 2, when they averaged about 17.5 cm and 55 g. One group was kept under a simulated natural photoperiod regime (Fig. 1) in fresh water until June 14 and then transferred to 30‰ sea water. A second group was subjected to the reciprocal photoperiod regime and fresh water until June 14 and sea water thereafter. Photoperiod regimes and light intensity, temperature, and salinity regulation were similar to those used by Saunders and Henderson (1970).

Standard rates of oxygen consumption were measured from August 3 to September 6. The rate for each fish was determined by measuring simultaneously the routine rate of oxygen consumption and spontaneous activity as described by Beamish and Mookherjii (1964). Our respirometer had a volume of 22 liters and was largely patterned after that used by Beamish and Mookherjii. The activity detector was a standard thermoregulator (Mathur and Shrivastava 1970) with its bulb immersed together with a 5-v DC heater across a 10-ohm resistance in a closed mercury reservoir. The heater was set to maintain the temperature in the mercury reservoir 2 degrees C higher than that of the water in the respirometer. Movements by the fish produced water currents which cooled the activity meter's bulb and caused the heater to come on. This increased the time that the heater needed to be in circuit to maintain the 2 C differential. This increase, measured by a resetable, cycling timer, was used as a measure of a fish's activity. An activity baseline was determined, at the beginning and end of each determination of oxygen consumption, by measuring the time the heater was in circuit with no fish in the respirometer.

For measurement of oxygen consumption, a fish was removed from the holding tank in the morning and allowed no food. In late afternoon it was anesthetized in M.S.-222, weighed, and measured and then placed in the respirometer with flowing water of the holding temperature and salinity. Light was excluded from the respirometer to reduce visual stimulation of the fish.

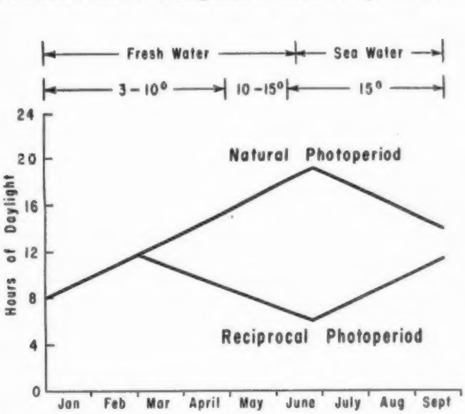

FIG. 1. Photoperiod regimes and other holding conditions for the two groups of postsmolts.

Oxygen consumption and activity, at 15 ± 0.2 C, were determined on the next 1 or 2 days between 0700 and 1800 hr. By this time the fish had not been fed for at least 36 hr.

Oxygen concentration in the water was measured by the Winkler method at the beginning and end of periods of respirometer closure. A Beckman macro oxygen electrode was used to monitor PO_2 in the respirometer to determine periods of closure and flushing. The fish were allowed to reduce the oxygen concentration in the closed respirometer only to 75% of the air saturation value, the time ranging from 27–92 min.

A minimum of six determinations were made for each fish, at intervals of at least 30 min for flushing the respirometer and restoration of the oxygen concentration to 95% of air saturation. The fish was removed after the final measurement and again weighed and measured.

In determining the standard rate of oxygen consumption for each fish, by extrapolating the line of best fit to zero activity (Beamish and Mookherjii 1964), little extrapolation was required because some activity values were usually close to zero. When the activity values were all close to zero, the standard rate was taken as the mean of the lowest three values.

The narrow weight range of our fish invalidated comparison of rates of oxygen consumption between groups by the usual method of plotting the log rate in mgO_2/hr against log fish weight and comparing slopes and intercepts (Winberg 1961; Saunders 1963). Finding no significant difference (by *t*-test) between mean weights of the two fish groups, we analyzed for differences in rates of oxygen consumption between groups using the *t*-test.

Results and discussion — Atlantic salmon smolts that had been subjected to the reciprocal photoperiod regime (Fig. 1) from early March had significantly lower ($P < 0.05$) standard rates of oxygen consumption in sea water in late summer (85.7 ± 8.9 (SE) mg/kg per hr, nine fish) than smolts held under a simulated natural photoperiod regime (111.2 ± 5.4, 11 fish). Mean weights were 194.2 ± 16.0 (SE) g for the reciprocal photoperiod and 226.5 ± 14.3 for the natutal photoperiod fish.

The lower rate of oxygen consumption in the reciprocal photoperiod fish and the previously reported reduced voluntary feeding and growth rates in similarly treated fish following transfer to sea water (Saunders and Henderson 1970) are indicative of a general metabolic suppression. The lower feeding and growth rates in the reciprocal photoperiod fish, though the two groups had similar feeding opportunities, are explainable on the basis of Brett's (1971) findings, with sockeye salmon (*Oncorhynchus nerka*) on a variety of diets, that reduced ration below an experimentally determined optimum leads to reduced gross efficiencies of food conversion. Whatever was responsible for the lower standard rate of oxygen consumption appears to be linked to a lower voluntary feeding rate, low growth rate, and depressed food conversion efficiency.

The reciprocal photoperiod regime may have resulted in the physiology of the salmon being shifted to a winter timetable. In support of this idea, Beamish (1964) reports seasonal differences in standard rates of oxygen consumption in other salmonids (brook trout, *Salvelinus fontinalis*, and brown trout, *Salmo trutta*), the rates being lower during late winter and spring than during autumn, the spawning season for both species. Our fish did not have ripe gonads or show obvious signs of gonadal development.

A possible basis for the different rates of oxygen consumption in the two groups of fish is different proportionate use of carbohydrate, fat, and protein. Under normal conditions, the parr–smolt transformation is characterized by an increase in nitrogen and fat metabolism and reduced storage of glycogen in the liver (Malikova 1959). Wendt and Saunders (1973) reported reduced liver glycogen stores and elevated blood glucose levels in hatchery-reared salmon during the parr–smolt transformation. In his review of the physiology of growth hormone in fishes, Ball (1969) suggests that this hormone plays a role in the complex of physiological changes during the transformation. In line with the reduced storage of fat and glycogen in the liver of smolts (Malikova 1959), it may be pertinent that Russell (1955) suggests that growth hormone promotes synthesis of protein from amino acids in mammals with fat supplying the energy for such synthesis. Further studies of the physiology of smolting should be aimed at finding a possible link between growth hormone production and changing patterns of carbohydrate, fat, and protein metabolism, particularly in response to photoperiod.

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Extended Analysis of Hybridization in Sunfishes (Centrarchidae) Using an Adjusted Hybrid Index Method

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KEENLEYSIDE, M. H. A., R. K. MISRA, AND D. W. BATESON. 1973. Extended analysis of hybridization in sunfishes (Centrarchidae) using an adjusted hybrid index method. J. Fish. Res. Board Can. 30: 1901–1904.

Sunfish collected from Pinehurst Lake, Ontario, were sorted into three groups: bluegill (*Lepomis macrochirus*), pumpkinseed (*L. gibbosus*), and a group possessing some of the color patterns of each of the other two. Eleven morphological characters of each fish were analyzed by a hybrid index method, and by an adjusted index which allowed: a) calculation of sampling variances of individual and mean index estimates and, b) testing of hypotheses about the position of suspected hybrids relative to the parental populations. This method, applied to single characters and to combinations of characters, showed that the anomalous group resembled bluegills in four characters, pumpkinseeds in one, and were exactly intermediate in the others. The simplest explanation of these results is that the intermediate group was a population of bluegill × pumpkinseed hybrids.

This use of the hybrid index permits increased precision over earlier methods in comparing suspected hybrid individuals with their putative parent populations.

KEENLEYSIDE, M. H. A., R. K. MISRA, AND D. W. BATESON. 1973. Extended analysis of hybridization in sunfishes (Centrarchidae) using an adjusted hybrid index method. J. Fish. Res. Board Can. 30: 1901–1904.

Les auteurs divisent en trois groupes des crapets collectionnés dans le lac Pinehurst, Ontario: crapet à oreilles bleues (*Lepomis macrochirus*), crapet-soleil (*L. gibbosus*), et un groupe possédant un motif de coloration intermédiaire entre les deux.

Ils analysent sur chaque poisson onze caractères morphologiques, à l'aide de la méthode de l'indice d'hybride, et d'une amplification de cet indice qui permet de: a) calculer la variance des estimés d'indices individuels et moyens et, b) vérifier les hypothèses relatives à la position des présumés hybrides vis-à-vis des populations de parents. Cette méthode, appliquée à des caractères individuels ou à des combinaisons de caractères, démontre invariablement que le groupe anormal se rapproche du crapet à oreilles bleues sous certains aspects, du crapet-soleil sous d'autres et enfin, dans certains cas, occupe une position intermédiaire. L'explication la plus simple de ces résultats est que le groupe intermédiaire est une population d'hybrides crapet à oreilles bleues × crapet-soleil.

L'emploi de l'indice d'hybride permet de comparer avec une plus grande précision que les méthodes antérieures les individus soupçonnés d'être des hybrides avec les populations de leurs parents putatifs.

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THE hybrid index, as developed by Hubbs and Kuronuma (1942) and Hubbs et al. (1943), has often been used to study cases of suspected hybridization between fishes. An amplification of the original hybrid index formulation of Hubbs et al. (1943) was developed by Misra et al. (1970) to allow estimation of: (i) the sampling variation based on single individuals and, (ii) hybrid indices for individuals, considered singly and as a group, based on two or more characters.

The method was illustrated with data from sunfishes (Centrarchidae) collected in Pinehurst Lake, Brant County, Ontario (Bateson 1970). This lake contains three distinct types of sunfish; two are readily identified as pumpkinseed (*Lepomis gibbosus*) and bluegill (*L. macrochirus*). The third type defies easy classification but is distinguishable by having some of the color patterns found on each of the other two. As hybrid sunfishes are generally intermediate between their parent species in many morphological characters including colors (Bailey and Lagler 1938; Hubbs 1955), the undetermined fish in Pinehurst Lake were suspected to be interspecific hybrids between bluegill and pumpkinseed. Data presented in the earlier paper were standard length, body depth, and head length of samples of

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TABLE 1. Means, ranges, and standard deviations (SD) of 11 measurements, in mm, of B, H, and P from Pinehurst Lake.

Character	Bluegill (N = 100)			Hybrid (N = 97)			Pumpkinseed (N = 81)		
	Mean	(range)	SD	Mean	(range)	SD	Mean	(range)	SD
Standard length	95.16	(71.4–117.0)	11.37	82.5	(60.9–110.0)	8.27	71.66	(52.0–114.4)	14.04
Body depth	41.99	(31.5–51.9)	5.24	38.1	(28.2–50.9)	3.77	32.39	(23.5–52.6)	6.68
Caudal peduncle depth	13.18	(9.9–16.3)	1.61	12.0	(8.8–16.0)	1.18	10.27	(7.5–16.4)	2.04
Caudal peduncle length	22.88	(17.2–28.1)	2.74	19.72	(14.5–26.3)	2.04	17.40	(12.6–27.8)	3.38
Head length	33.94	(25.5–41.7)	4.06	32.07	(23.8–42.9)	3.11	26.82	(19.5–42.8)	5.34
Upper jaw length	10.40	(7.8–12.8)	1.26	9.70	(7.2–12.9)	0.95	8.41	(6.1–13.4)	1.70
Snout length	8.70	(6.5–10.7)	1.04	8.29	(6.1–11.1)	0.89	7.34	(5.3–11.7)	1.45
Orbit length	9.67	(7.3–11.8)	1.16	8.07	(5.9–10.6)	0.89	7.57	(5.5–12.1)	1.45
Pectoral fin length	29.68	(22.3–36.5)	3.56	26.72	(19.7–35.6)	2.86	24.42	(17.7–38.9)	4.79
Anal spine length	18.47	(13.9–23.0)	2.23	17.13	(12.6–26.0)	1.92	14.15	(10.3–22.6)	2.76
Gill raker length	3.45	(2.6–4.2)	0.44	2.39	(2.0–3.1)	0.29	1.86	(1.3–3.0)	0.39

the three types of fishes (Misra et al. 1970). The present report extends the illustration of the amplified hybrid index method by presenting seven more measurements from the same fish samples.

Fish were collected, sorted, and measured as described previously (Misra et al. 1970). In this report pumpkinseeds, bluegills, and their suspected hybrids are referred to as P, B, and H, respectively. P is designated as parent 1 and B as parent 2, corresponding to 0 and 100, respectively, on the hybrid index scale.

As in the earlier paper three null hypotheses about H, as individuals and as a group, were tested: H were identical with P or with B or were exactly intermediate.

Scale ageing of the subsamples showed all fish to be in the IV + year class. Ratios of males to females were: B, 98:2; P, 56:25; and H, 97:0. As no sex differences were found in any population for any of the 11 characters ($p > 0.05$, t-test), the sexes were not treated separately in the ensuing analysis.

For each of the 11 characters the mean B value was larger than the mean H value, which was larger than the mean P value (Table 1).

Results — On the basis of initial (i.e. unadjusted) hybrid index estimates, the mean index values were intermediate for each character (Table 2). As the ranges indicate, some of the values for each character except gill raker length exceeded both parental values on the 0–100 scale. However, testing the null hypothesis of exact intermediacy for each individual hybrid index value characterized 89 or more of the 97 H as exactly intermediate between the parental populations for each character.

It was shown by Misra et al. (1970) that for two characters which are reasonably well correlated, hybrid indices estimated after adjusting the second character for its correlation with the first will have a considerably smaller sampling variation than the initial, unadjusted indices. The adjusted hybrid index can therefore reveal the pattern of possible hybridization more effectively. This is shown in the present study as the ranges and standard errors of the adjusted hybrid indices (Table 2b) were considerably smaller than the corresponding statistics for the initial hybrid indices. Standard length was highly correlated with each character in all three samples ($0.78 < r < 0.99$), and was used to adjust each of the 10 characters of Table 2b. The mean

TABLE 2. Means and ranges of estimates by the two methods, standard errors (SE) of the means, and numbers of hybrids which were exactly intermediate or closer to either parent.

				Numbers of H		
Character	Mean	Range	SE	Closer to P	Intermediate	Closer to B
			(a) Initial hybrid index			
Standard length	46.4	−45.8 to 163.1	3.5	2	92	3
Body depth	59.8	−43.7 to 192.8	4.0	1	92	4
Caudal peduncle depth	58.7	−50.4 to 196.8	4.1	1	91	5
Caudal peduncle length	42.6	−53.0 to 162.5	3.7	3	90	4
Head length	73.4	−42.3 to 225.7	4.4	1	92	4
Upper jaw length	64.6	−60.8 to 225.9	4.8	1	92	4
Snout length	69.4	−90.5 to 275.3	6.5	1	90	6
Orbit length	24.2	−79.5 to 144.5	4.2	6	89	2
Pectoral fin length	44.1	−89.8 to 212.7	5.4	2	91	4
Anal spine length	68.6	−36.0 to 274.4	4.5	0	93	4
Gill raker length	33.6	−8.7 to 78.2	1.8	7	90	0
			(b) Adjusted hybrid index			
Body depth	62.3	42.8 to 87.3	0.4	0	8	89
Caudal peduncle depth	61.3	43.8 to 78.5	0.4	0	8	89
Caudal peduncle length	44.9	17.9 to 90.3	0.8	4	90	3
Head length	75.9	27.9 to 86.2	0.7	1	3	93
Upper jaw length	67.7	41.3 to 112.3	0.9	0	28	69
Snout length	72.9	−0.2 to 164.7	1.9	2	89	6
Orbit length	26.9	−22.8 to 68.4	1.2	69	28	0
Pectoral fin length	47.4	−95.9 to 90.2	1.8	2	95	0
Anal spine length	70.9	10.9 to 225.1	1.9	1	93	3
Gill raker length	34.7	−4.3 to 78.6	1.1	11	85	1

adjusted index values indicate that H values were intermediate for each character. The ranges of individual indices for the first four characters were within the limits set by P and B. However, the ranges for the other six characters show that some H indices exceeded those of one or both parents. Finally, testing the null hypothesis of exact intermediacy for each individual adjusted hybrid index value characterized most H as exactly intermediate in five characters, closer to P in one character (orbit length), and closer to B in four characters.

Discussion — The suspected hybrid sunfish from Pinehurst Lake are clearly intermediate between the bluegill and pumpkinseed populations of the same lake. Intermediacy is shown by the presence of bluegill-like and pumpkinseed-like characters in fish of the anomalous group. Supporting evidence comes from color patterns, mean values of 11 morphological characters, and analysis of the latter data by the hybrid index method of Hubbs et al. (1943) and by an adjusted form of the hybrid index as developed by Misra et al. (1970). The simplest explanation of this situation is that the intermediate fish are hybrid offspring of P and B. The H do not conform to published descriptions of any centrarchid species (Trautman 1957; Hubbs and Lagler 1964), but they are similar in several characters to fish presumed or known to be offspring of P-B mating (Hubbs 1920; Hubbs and Hubbs 1933; Bailey and Lagler 1938; Lagler and Steinmetz 1957).

The P sex ratio of 56:25 may have been biased towards males because many P in the sample were males taken from their nests by angling, the most effective fishing method in the thick weed-beds close to shore. The B ratio of 98:2 is difficult to explain except on the basis of nonrandom sampling. Female B have been seen swimming in the lake and spawning with male B (D. W. Bateson, personal observation), and the presence of large numbers of B in the lake indicates that females are present in numbers adequate for frequent spawning. All H captured were male, corresponding to the all-male or majority-male status of many other hybrid centrarchid populations (Hubbs 1955). However, considering the B sex ratio, nonrandom sampling cannot be ruled out for the H sample. No other data are available on sex ratios or population size for any of the three *Lepomis* populations in Pinehurst Lake. Unbalanced sex ratios in P and/or B may have been one of the conditions promoting hybridization, as suggested by Hubbs (1955) and Bailey and Lagler (1938), but the precise causes of the interspecific breeding in Pinehurst Lake are not known (Bateson 1970).

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Food, Feeding, and Condition of Lobsters, *Homarus americanus*, Throughout the Seasonal Cycle in Bonavista Bay, Newfoundland

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Ennis, G. P. 1973. Food, feeding, and condition of lobsters, *Homarus americanus*, throughout the seasonal cycle in Bonavista Bay, Newfoundland. J. Fish. Res. Board Can. 30: 1905–1909.

The rock crab, *Cancer irroratus*, and spider crab, *Hyas araneus*, made up about 50% of the food of lobsters in Bonavista Bay, Nfld. The sea urchin, *Strongylocentrotus dröbachiensis*, several species of molluscs, and several species of sea stars made up 7.1, 10.9, and 10%, respectively. The remainder was mainly a variety of bottom invertebrates but fish and seaweeds were also fairly common. There was a change to a slightly more calcium-rich diet during the molting season. A rapid increase in feeding activity during the summer coincided with increasing temperatures, but despite decreasing temperatures during the fall, feeding activity remained high. The feeding index for females remained high longer into the winter than for males. Physiological condition was directly related to the molting cycle. Premolt condition was very high, postmolt very low, and recovery to the intermolt condition was attained about 2½ months after the peak molting period.

Ennis, G. P. 1973. Food, feeding, and condition of lobsters, *Homarus americanus*, throughout the seasonal cycle in Bonavista Bay, Newfoundland. J. Fish. Res. Board Can. 30: 1905–1909.

Le crabe commun, *Cancer irroratus*, et le crabe araignée, *Hyas araneus*, constituent environ 50% de la nourriture du homard dans la baie Bonavista, T.-N. L'oursin vert, *Strongylocentrotus dröbachiensis*, plusieurs espèces de mollusques et plusieurs espèces d'étoiles de mer constituent 7.1, 10.9 et 10% respectivement. La balance est formée surtout d'un assortiment d'invertébrés benthiques. On observe un changement en direction d'un régime légèrement plus riche en calcium durant la saison de mue. Une rapide augmentation d'activité alimentaire, du début du printemps à la fin de l'été, coïncide avec une élévation de température mais, en dépit de l'abaissement de la température en automne, l'alimentation se poursuit activement. L'indice d'alimentation des femelles demeure élevé plus longtemps en hiver que celui des mâles. La condition physiologique est directement liée au cycle de la mue. Elle est à un niveau très élevée avant la mue, très bas après la mue, et le retour à la condition d'intermue se produit environ 2½ mois après la période de pointe de la mue.

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This paper describes the natural food of the American lobster, *Homarus americanus*, in Bonavista Bay, Nfld., also seasonal changes in food and feeding activity and how this relates to physiological condition.

Homarus americanus is an omnivorous feeder and the bulk of its natural food is made up of a variety of bottom invertebrates, mainly crabs, polychaetes, mussels, periwinkles, sea urchins, and sea stars, but fish and seaweeds are also eaten (Herrick 1911; Squires 1970; Weiss 1970; Miller et al. 1971). The percentage occurrence of the various prey species in lobster stomachs varies considerably from one area to another and there is evidence that lobster stomach contents reflect the relative abundance of prey species in the habitat (Miller et al. 1971). Mann and Breen (1972) suggest that in many eastern Canadian coastal areas the lobster may prevent overgrazing of seaweeds by controlling sea urchin populations. However, in Newfoundland coastal waters predation by lobsters and other species apparently is not effective in limiting the abundance of sea urchins (Himmelman and Steele 1971). Lobsters are primarily predators (Weiss 1970; Miller et al. 1971) but scavenging behavior is also well developed (Herrick 1911) and the trap fishery for lobsters depends on their attraction to bait.

Materials and methods — Samples of lobsters ranging in carapace length from 47 to 113 mm were obtained by scuba divers near St. Chads, Bonavista Bay, Nfld. at irregular intervals from July 1968 to March 1970.

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Blood samples were taken from the lobsters throughout the period and stomachs were obtained from February 1969 onwards. A total of 523 blood samples was analyzed for serum protein concentration which was used as an index of physiological condition (Stewart et al. 1967b; Stewart and Li 1969). The food contents of 288 stomachs were examined and identified as far as possible. A visual estimate of stomach fullness (feeding index) as well as an estimate of the proportion of the total stomach contents made up by the various food items contained in the stomach were made using a scale from 1 to 10 for each. Carapace length, sex, state of maturity of females, and shell condition during the molting season were recorded.

Results and discussion — Two other decapod crustaceans, the rock crab, *Cancer irroratus*, and the spider crab, *Hyas araneus*, were the main food of lobsters in this study area and together they made up about half the total amount of food consumed (Table 1). The sea uchin, *Strongylocentrotus dröbachiensis*, was the next important single species making up 7.1% of the total food; several species of molluscs made up 10.9% and several species of sea stars made up 10%. The remainder of the food was mainly a variety of other bottom invertebrates, but some fish and seaweeds were also eaten.

There was some seasonal variation in diet (Table 2). Although crabs made up the bulk of the food throughout the year, they made up a much smaller proportion of the total amount of food during July, August, September than at other times of year. During this period sea stars and sea urchins made up a much greater proportion than at other times. This change to what is probably a more calcium-rich diet coincided with the molting season and it did not appear to reflect a relative change in abundance of the prey species. It may have resulted from active food selection by the lobsters. Hickman (1946) correlated a predominance of molluscan material with a peak catch of newly molted spiny lobster females and suggested preferential feeding on calcareous food for the necessary hardening of the skeleton. Most of the crab remains could not be positively identified as one species or the other but from what could be identified it appeared that both species were eaten with more or less equal frequency during June–December but throughout the remainder of the winter and spring it appeared to be mainly the spider crab that was eaten. The rock crab is more seclusive and shelter-seeking than the spider crab, particularly during the winter months, making the spider crab more readily available during this period. The slight change in diet more likely reflects this change in availability rather than a relative change in abundance or distribution of the two species. There was no indication of any difference in diet between male and female lobsters or between size groups.

Lobsters are predatory and appear to be capable of active food selection as well as capture of very mobile prey. Crabs compose such a large proportion

TABLE 1. Frequency of occurrence and proportion of total food of various stomach contents of *Homarus americanus* in Bonavista Bay, Nfld.

Stomach contents	Freq. of occurrence (%)	% total food
Crustacea		
crabs — *Cancer irroratus*, *Hyas araneus*, and only rarely *Pagurus arcuatus*	81.3	49.8
unidentified crustacean remains, chitinous shell fragments, amphipods	2.4	.9
Mollusca		
scallop, clam, chiton, and limpet shell fragments	22.6	3.6
mussel *Mytilus edulis*, *Volsella modiolus*, shell fragments	28.1	3.3
unidentified calcareous shell fragments	17.0	.8
periwinkle operculae mainly of *Littorina littorea*	18.8	3.2
Echinoderms		
sea urchin *Strongylocentrotus drõbachiensis*	37.2	7.1
sea stars — several common species including *Asterias vulgaris*, *Leptasterias polaris*, *Solaster endeca*, *Ophiopholis aculeatus*	24.0	10.0
Polychaeta		
mostly jaws	25.3	2.5
Other invertebrates		
tunicates, sea anemones, jelly-fish, sponges	15.6	4.9
Fish		
scales, vertebrae, bones	10.4	3.3
Seaweeds	13.5	1.6
Unidentified	45.1	7.4
Nonfood		
coarse sand grains	28.5	1.5
rubber, metal, rope fragments	3.1	.1

TABLE 2. Proportion of total stomach contents (%) of major food items for various samples throughout the year.

	Sampling dates								
	Feb. 5–11	Apr. 10–17	June 11–13	July 14–17	Aug. 20–Sept. 10	Nov. 18–19	Dec. 16–18	Jan. 21–Feb. 26	Mar. 18–19
Crab remains	61.3	54.2	49.2	34.0	44.6	54.4	69.9	72.1	41.4
Periwinkle operculae	4.9	1.5	4.9	3.8	1.0	4.7	.4	4.8	.9
Calcareous shell fragments	3.1	1.8	.9	–	.2	.2	1.0	2.2	1.6
Sea urchin remains	2.9	2.2	3.2	8.9	17.2	6.5	9.2	.3	2.1
Sea star remains	2.2	8.9	7.8	21.8	8.4	7.3	7.4	.3	8.3
Mussel shell fragments	2.3	3.5	5.0	5.7	3.9	.1	.7	1.0	4.9
Polychaete remains	.2	4.0	3.0	4.2	4.3	.1	.1	.1	.9
Fish remains	–	.1	4.8	1.7	4.7	7.3	1.1	3.2	1.0
No. examined	37	57	49	42	27	33	14	14	15

of the diet that it seems very unlikely that they would all be taken dead. Fish remains were fairly common and some are probably taken alive as well.

Stomach fullness has certain shortcomings as an index of feeding activity. It does not consider temperature related changes in metabolic and digestive rates nor different times required for digestion of different foods. A physiological index of feeding activity would be higher during periods of high temperature and lower during periods of low temperature than a stomach fullness index shows. However, in this study seasonal changes in the stomach fullness index were so marked that it is considered to be an adequate index of seasonal changes in feeding activity.

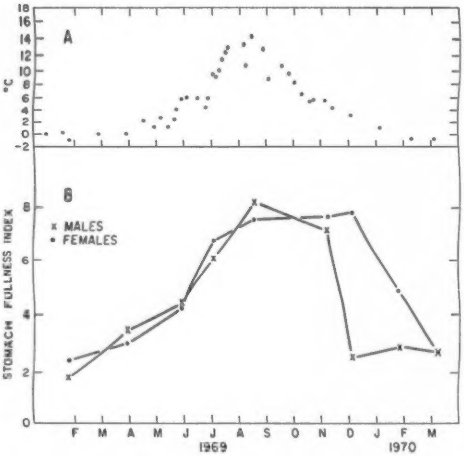

FIG. 1. (A) Temperatures on the bottom at 30 ft (9.0 m) throughout the sampling period and (B) seasonal changes in feeding activity (stomach fullness index) for *Homarus americanus* in Bonavista Bay, Nfld.

During midwinter to early summer there was a gradual increase in feeding activity but during the summer the increase to peak feeding activity was more rapid. These increases coincided with increasing temperatures during the periods (Fig. 1), but even when temperatures started to fall in September feeding activity remained high. There was very little difference between males and females except during early winter. During the period late November to about mid-December the stomach fullness index for males dropped sharply, but for females it remained high and did not drop to the same level as males until around mid-February to mid-March. Too few ovigerous females were obtained for separate analysis (they are included in Fig. 1) but the stomach fullness index of those obtained ranged from less than 1 to 10.

Changes in physiological condition as determined by serum protein concentration were directly related to the molting cycle (Fig. 2). During the intermolt period (December–June) serum protein averaged between 35–40 mg/ml, but in the premolt period (August) it averaged between 60–65 mg/ml. The postmolt average was between 20–25 mg/ml. Physiological recovery from molting was fairly rapid and the intermolt condition was reached by mid-November about 2½ months after the peak molting period.

To accomplish this physiological recovery from molting, lobsters have to maintain a high level of feeding activity throughout the fall despite declining temperatures. Females continue feeding at a high level longer into the winter than males, yet there is very little difference in physiological condition between the sexes at this or any other time. The difference in feeding activity between the sexes in the late

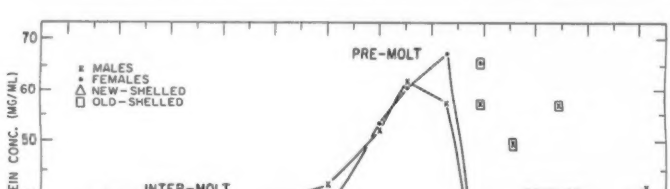

FIG. 2. Seasonal changes in serum protein concentration for *H. americanus* in Bonavista Bay, Nfld. Old and new shelled lobsters separated during pre- and postmolt periods. Ovigerous females not included.

fall–early winter period may be caused by greater physiological demands on the female because of gonad development.

Acknowledgments — I am grateful to technicians G. E. Tucker and G. Dawe who assisted in collection and laboratory analysis of the samples; also to the Master and crew of the M. V. *Parr* who supported diving operations throughout most of the period.

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First Records of the Chinese Mitten Crab, *Eriocheir sinensis*, (Crustacea:Brachyura) from North America[1]

S. J. NEPSZY AND J. H. LEACH

Ontario Ministry of Natural Resources
Lake Erie Fisheries Research Station, Wheatley, Ont.

NEPSZY, S. J., AND J. H. LEACH. 1973. First records of the Chinese mitten crab, *Eriocheir sinensis*, (Crustacea:Brachyura) from North America. J. Fish. Res. Board Can. 30: 1909–1910.

Three specimens of the Chinese mitten crab, *Eriocheir sinensis*, were captured commercially by gillnets in Lake Erie in April and May, 1973, and one was taken from a water-intake pipe in the Detroit River in 1965. These are the first published records of this species for North America. The hazard of establishment of this catadromous crab in North America is discussed.

NEPSZY, S. J., AND J. H. LEACH. 1973. First records of the Chinese mitten crab, *Eriocheir sinensis*, (Crustacea:Brachyura) from North America. J. Fish. Res. Board Can. 30: 1909–1910.

Trois crabes-chinois, *Eriocheir sinensis*, ont été capturés dans des filets maillants de pêche commerciale dans le lac Erié en avril et mai 1973, et un autre a été capturé dans une prise d'eau dans la rivière Détroit en 1965. Ce sont les premières mentions publiées pour l'Amérique du Nord.

Nous passons brièvement en revue l'invasion européenne, la distribution et les moeurs de ce crabe catadrome et discutons des dangers que présente son établissement en Amérique du Nord.

Received July 18, 1973

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[1] Contribution 73–7 of the Ontario Ministry of Natural Resources, Fish and Wildlife Research Branch, Maple, Ont.

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Three specimens of the Chinese mitten crab, *Eriocheir sinensis* H. Milne Edwards, were captured commercially by gillnets in Lake Erie in April and May, 1973. Also, a specimen was collected from a water-intake pipe opposite Belle Isle in the Detroit River at Windsor, Ont. in October 1965. The Belle Isle specimen, a male, was identified by Dr J. Winner, Department of Biology, University of Windsor and Dr F. A. Chace Jr., Smithsonian Institution, Washington, D.C. The Lake Erie specimens, two males and one female, were captured within a 40-km radius.

The carapace lengths for the four specimens ranged from 57.3 to 64.3 mm and the widths from 65.0 to 74.4 mm. The total weights of the Lake Erie specimens ranged from 124.5 to 201.1 g.

The crab, a catadromous species with a thick mass of hair on each of the chelipeds, is indigenous to the low-lying areas of northern China and as far south as Shanghai. In Europe, where it was found in 1912 in a tributary of the Weser River in Germany, it has spread to the south of France (Hoestlandt 1959) and is spreading to low-lying areas of Germany, Scandinavia, Holland, and Belgium (Kaestner 1970).

Presumably the crabs were carried to Lake Erie in ballast tanks of a ship or ships, as Peters and Panning (1933) considered they may have been carried to Europe. As the Welland Canal was opened for shipping only 15 days before the first Lake Erie crab was captured, the animals may have been in the lake since the previous shipping season or longer.

The crab is a serious pest in Europe, where it causes erosion of river banks because of its burrowing habit (Peters and Panning 1933). It damages nets, eats bait and netted fish, and reduces potential fish food.

Though the crab is unlikely to become established in Lake Erie or the upper Great Lakes, accidental introduction to an estuarine system might permit it to become established in North America. The crab is a lowland form that needs not only sea or brackish water for its propagation but also the mouths of large rivers not subject to strong currents (Panning 1950). The normal habitat of the adults in Europe is the bottoms and banks of freshwater rivers and estuaries; individuals prefer hard bottom and areas covered with submerged plants, which are the main food source (Pape 1939). The crab regularly migrates 700 km up the Elbe River in Germany and 750 km up the Yangtze Kiang in China and has been found up to 1400 km from the sea; in Europe, it bypasses obstacles such as dams and survives up to 38 days in wet meadows (Kaestner 1970).

Acknowledgments — We thank commercial fishermen R. Wrightsell and L. Vaughan of Erieau and M. Berry of Port Stanley, who caught and brought the crabs to our attention; H. Vidler of Erieau, who brought the first two specimens to us for study and identification; Dr D. Barr of the Royal Ontario Museum, Toronto, who verified identification of the crabs taken in 1973; Dr E. Bousfield of the National Museum of Natural Sciences, Ottawa, who permitted data on the crab in the museum collection to be quoted; and Drs F. Chace Jr., D. Barr, and I. Ball, who critically reviewed the manuscript.

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Hirundichthys rondeleti, Cookeolus boops, Priacanthus arenatus, Seriola dumerili, Four Species New to the Canadian Atlantic Ichthyofauna[1]

K. T. MacKay[2]

Fisheries and Marine Service
Marine Ecology Laboratory, Bedford Institute of Oceanography, Dartmouth, N.S.

and J. Gilhen

Nova Scotia Museum, Halifax, N.S.

MacKay, K. T., and J. Gilhen. 1973. *Hirundichthys rondeleti, Cookeolus boops, Priacanthus arenatus, Seriola dumerili,* four species new to Canadian Atlantic ichthyofauna. J. Fish. Res. Board Can. 30: 1911–1913.

The flyingfish, *Hirundichthys rondeleti,* two priacanthids, *Cookeolus boops* and *Priacanthus arenatus,* and the carangid, *Seriola dumerili* are reported for Canadian Atlantic waters. Single specimens of each species were captured during August–November 1970–72, in the vicinity of Prospect Bay or St. Margaret's Bay, Nova Scotia. This is the first record of each species north of Cape Cod, Mass.

MacKay, K. T., and J. Gilhen. 1973. *Hirundichthys rondeleti, Cookeolus boops, Priacanthus arenatus, Seriola dumerili,* four species new to Canadian Atlantic ichthyofauna. J. Fish. Res. Board Can. 30: 1911–1913.

Les auteurs signalent la présence de l'exocet, *Hirundichthys rondeleti,* deux priacanthides, *Cookeolus boops* et *Priacanthus arenatus,* et la sériole, *Seriola dumerili,* dans les eaux canadiennes de l'Atlantique. Un seul spécimen de chaque espèce a été capturé durant la période d'août–november 1970–72, dans les environs des baies Prospect ou St. Margaret, Nouvelle-Ecosse. C'est la première mention de ces espèces au nord du cap Cod, Mass.

Received June 8, 1973

St. Margaret's Bay (lat 44°30′-44°40′, long 63°56′-64°04′E) is a south facing U-shaped bay 16 km (10 miles) in length, located 40 km (20 miles) west of Halifax on the Atlantic coast of Nova Scotia. Seasonal variations are similar to those of oceanic waters but wide short-term fluctuations occur in temperature and salinity. Surface temperatures are below 1 C during January–March; warming occurs in the spring to between 5–8 C by the end of May; warming continues gradually with surface temperatures reaching a maximum of 15–18 C in August. A well-developed thermocline is present during the summer at 5–20 m. Cooling proceeds slowly until November when surface temperatures are about 10 C and then rapidly to about 1 C by the end of December.

Prospect Bay is midway between Halifax and St. Margaret's Bay. It is a shallow narrow bay which is more influenced by land drainage than St. Margaret's Bay and the summer surface temperatures may be as high as 23 C.

Both bays may be occasionally influenced by eddies which break away from the Gulf stream system and carry with them the associated fauna (Hachey 1961).

Increased research activity and contact with fishermen in these two areas over a 5-year period has resulted in the collection of 31 species of fish from southern warmer waters (K. T. Mackay and J. Gilhen unpublished data). Four of these species are new records for Canadian Atlantic waters and are reported here.

Methods

Specimens were obtained from commercial fishermen, and were preserved in 10% formalin, either directly, or after a period of frozen storage. Lengths, total (TL) or standard (SL), and weights were taken from fresh or preserved specimens. The methods of measurement follow those outlined by Hubbs and Lagler (1958). The classification to family, genus, and species and the common names follow Bailey et al. (1970).

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[2] Present address: Biology Department, St. Francis Xavier University, Sydney, N.S.

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The specimens are in the Nova Scotia Museum, Halifax, the Royal Ontario Museum, Toronto, or the National Museum of Natural Sciences, Ottawa. Detailed locality and biological data are on file at the Nova Scotia Museum.

Results

FAMILY: EXOCOETIDAE

Hirundichthys rondeleti (*Valenciennes*) *Blackwing flyingfish* — A single specimen (225 mm TL) was captured alive in Prospect Harbour on August 9, 1970 (NSM 970-Z-156). This is a significant range extension as this is a tropical species of both Atlantic and Pacific waters and has been reported only once from North America and that in the Florida Keys (Starck 1968).

FAMILY: PRIACANTHIDAE

Cookeolus boops (*Bloch and Schneider*) *Bulleye* — A single specimen (147 mm TL) was captured in a mackerel trapnet at Indian Point, St. Margaret's Bay, September 16, 1971 (NSM 972-Z-2). The specimen was captured alive and was copper-colored; it turned a brilliant red when frozen. The trailing edges of the pelvics were tinged with black. Caldwell (1962) gives Cape May, New Jersey as the most northerly record. This specimen is the 14th recorded for the western North Atlantic (Anderson et al. 1972), the first for Canadian waters, and represents a significant northward range extension of 1165 km.

Priacanthus arenatus, Cuvier Bigeye — A prejuvenile (about 41.7 mm SL) was taken from the pharynx of a small pollock, *Pollachius virens*, which was captured by baited hook and line at Gulch Shoal, off Hopson Island, Halifax County on September 8, 1972 (NMC 72–245). This specimen was difficult to identify to species, because of it's small size and the fact that the gill racker count was intermediate between *Priacanthus cruentatus* and *P. arenatus* (Caldwell 1962). The short pelvic fin which would normally suggest *P. cruentatus* may have been broken. The specimen has been examined by Dr D. E. McAllister, National Museum of Natural Sciences, Ottawa, and a description and photograph was sent to Dr D. K. Caldwell, University of Florida, St. Augustine. Their consensus is that the specimen is probably *P. arenatus*. Caldwell (1962) lists Massachusetts as the northernmost record for this species. This prejuvenile, therefore, represents a significant northward range extension and is the first record for the Canadian Atlantic.

FAMILY: CARANGIDAE

Seriola dumerili (*Risso*) *Greater amberjack* — A single specimen (211 mm SL) was captured November 2, 1970, near Prospect (NSM 970-Z-414). The normal range of this species is south of Cape Hatteras, with smaller specimens occasionally being taken north of Cape Hatteras (Perlmutter 1961). Leim (1930) has reported this species from near Liverpool, N.S. but Bigelow and Schroeder (1953) while erroneously locating the capture as Halifax consider Leim's specimen as *S. zonata*. This present record is the first for Canadian waters and probably the first north of Cape Cod (Mather 1958).

Discussion

These four species of southern fishes are all new records for the Canadian Atlantic and represent significant northward range extensions. Their records support the contention (K. T. MacKay and J. Gilhen unpublished data), that strays from more southern, warmer waters are a normal component of the Canadian Atlantic ichthyofauna during August–November, the period of warmest surface temperature.

Acknowledgments

We are grateful to the commercial fishermen and Fisheries Inspection Officiers of St. Margaret's Bay and Prospect, for their useful information and specimens of fish. Dr W. B. Scott, Royal Ontario Museum, Toronto and Dr D. E. McAllister, National Museum of Natural Science, Ottawa, assisted in identification of species and Dr B. S. Muir offered useful comments on the manuscript.

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Translation Series

The following translations have been prepared by or for the Fisheries and Marine Service, for use in its investigations. A limited number of copies are available for distribution as long as the supply lasts, or may be obtained by interlibrary loan, from the station where the translation has been deposited. Information on translations generally may be obtained from the Office of the Editor.

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Additional Publications

The Board also publishes a series of *Bulletins*, each on a specific topic. These are for sale by Information Canada, Ottawa, and remittances must be in advance, payable in Canadian funds to the order of the Receiver General of Canada. *Bulletins* are also available from local booksellers and Information Canada bookshops throughout Canada.

The *Annual Report* of the Board and the biennial *Review* of investigations are available free, on request. All publications may be referred to at Board establishments located at: Ottawa; Nanaimo, Vancouver, and West Vancouver, B.C.; Winnipeg, Man.; Ste. Anne de Bellevue, Que.; St. Andrews, N.B.; Halifax and Dartmouth, N.S.; and St. John's, Nfld.

L'Office publie également une série de *Bulletins*, chacun traitant sur un sujet spécifique. Les publications de l'ORP sont vendues par Information Canada à Ottawa. Les remises, payables d'avance en monnaie canadienne, doivent être établies à l'ordre du Receveur général du Canada. Les *Bulletins* sont aussi en vente chez votre libraire et dans les librairies d'Information Canada.

Vous pouvez obtenir le Rapport Annuel et la Revue biennale gratuitement. On peut consulter ces ouvrages aux établissements de l'Office situés à Ottawa (Ont.) à Nanaïmo, à Vancouver, et à Vancouver Ouest (C.-B.), à Winnipeg (Man.), à Ste-Anne-de-Bellevue (P.Q.), à St-Andrews (N.-B.), à Halifax et à Dartmouth (N.-E.), et à St-Jean (T.-N.).

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Guide to Authors

A more detailed guide on preparation of manuscripts from theses is available from the Office of the Editor.

EDITORIAL PRACTICES

The *Style Manual for Biological Journals* (3rd ed. American Institute of Biological Sciences, 3900 Wisconsin Ave. NW., Washington, D.C.) is used as the authority in matters of form. The standards for spelling are: *Webster's Third New International Dictionary* and *le Grand Larousse Encyclopédique*. Titles of periodicals are abbreviated as in the *Biological Abstracts* list. References to literature are made by the name-and-year system. The *Journal* follows the names and spelling recommended in *A List of Common and Scientific Names of Fishes from the United States and Canada* (Third Edition, 1970), Special Publication No. 6 of the American Fisheries Society.

Notes are distinguished from *papers* on the basis of scope or completeness, rather than quality, of the research. They may be on problems with narrow, readily defined limits; on work that is largely confirmatory; on fishing gear or methods, or research techniques; on advances in knowledge arising as by-products of broader studies; on progress in projects that were discontinued; or on preliminary findings that warrant publication before problems are resolved. They may be organized with as much flexibility as papers except that they may have no centered headings. They should take no more than four pages in the *Journal*.

Series titles should be avoided. An *abstract* is required. Authors are encouraged to submit abstracts in both English and French; those submitted in one language only are translated by the *Journal*.

Line drawings are preferably made with black india ink on white drawing or tracing paper or on coordinate paper with blue grids. All lines, symbols, letters, and numerals must be neat, and at least 1 mm high when the illustration is reduced to the appropriate size. Drawings should be grouped to facilitate comparisons. Originals must be submitted and should be less than 50 cm in the greater dimension for full-page illustrations, and proportionately smaller for those taking less than a page. Drawings must not be rolled for mailing.

Photographs should be printed on glossy paper with a wide range in tone. They should be cropped, squared, and mounted on white cardboard, with no spaces between those arranged in groups.

Galley proof is sent to the author, and he is responsible for detecting errors in printing as well as in content.

Fifty *reprints*, without covers, are supplied free. Additional copies may be ordered when the galley proof is returned. A charge of $30.00 per page is made for articles published. When submitting a manuscript, an author should state that his institution will accept this charge.

CHECKLIST ON MANUSCRIPTS

Attention to the following questions will expedite appraisal of manuscripts by referees and editors.

Are the findings, interpretations, and conclusions adequately documented and relevant to the purpose of the study?

Are all the tables and figures needed, and organized to facilitate comparisons? Are there inconsistencies between tables or figures and the text, or within the text? Should some of the data be made available separately, in a manuscript report or at a data repository? If you use statistical analysis are the statistics subordinate to the biology?

Would any of the text be clearer if condensed? Are summary statements given at the beginnings of sections and paragraphs, and are details in sections and paragraphs relevant to their topics? Does the organization of the manuscript follow logically from the statement of purpose in the introduction?

Does the *title* encompass the content of the report?

Does the *abstract* give the essentials of the new knowledge?

Is the *introduction* largely limited to the scope, purpose, and rationale of the study? Is review of the literature limited to defining the problem?

Are details of *materials and methods* limited to what scientists need in understanding the design of the study and in judging adequacy of the data?

Are generalizations on the *results* adequate? Are findings distinguished from inferences from them?

Is *discussion* limited to interpretation and significance of the findings?

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Guide des Auteurs

On peut se procurer au bureau du Directeur de la publication un guide plus détaillé pour la préparation de manuscrits à partir de thèses.

DISPOSITIONS GÉNÉRALES

Le *Style Manual for Biological Journals* (3e éd., publié par l'American Institute of Biological Sciences, 3900 avenue Wisconsin N.O., Washington, D.C.) sert de guide quant à la forme de présentation. Le *Webster's Third New International Dictionary* et le *Grand Larousse Encyclopédique* font autorité pour l'orthographe des mots. Les titres de périodiques sont abrégés suivant les *Biological Abstracts*. Les références bibliographiques dans le texte doivent suivre le système nom de l'auteur-année. Pour les noms de poissons et leur orthographe, le *Journal* suit les recommandations contenues dans *A List of Common and Scientific Names of Fishes from the United States and Canada* (Troisième édition, 1970), Publication spéciale No. 6 de l'American Fisheries Society.

Les *notes* se distinguent des *articles* par la portée et le degré d'achèvement, plutôt que par la qualité des recherches. Les notes peuvent traiter de problèmes à portée restreinte et facilement définissables; de travaux qui en corroborent d'autres; d'engins et de méthodes de pêche, ou de techniques de recherche; de découvertes dérivées d'une recherche de plus grande envergure; de progrès accomplis dans l'exécution de projets abandonnés; enfin, de résultats préliminaires assez importants pour en justifier la publication avant la solution complète du problème. L'agencement des notes peut être aussi flexible que celui des articles, sauf qu'elles ne doivent pas avoir d'en-têtes de paragraphes centrés. La longueur ne doit pas dépasser quatre pages.

On doit en général éviter les *titres en séries*. L'auteur doit fournir un *résumé*. Si possible, le résumé devra être produit en anglais et en français; le *Journal* se charge de la traduction des résumés soumis en une seule langue.

Les *dessins au trait* doivent être éxécutés de préférence à l'encre de Chine sur papier à dessin blanc, sur papier à calquer ou sur papier quadrillé bleu. Lignes, symboles, lettres et chiffres doivent être soignés et mesurer au moins 1 mm de hauteur lorsque la figure est réduite à la dimension voulue. On groupera les dessins de façon à faciliter les comparaisons. Les dessins originaux doivent accompagner le manuscrit, et ne doivent pas dépasser 50 cm dans le sens le plus long s'ils représentent une figure devant couvrir une page entière; ils seront proportionnellement plus petits pour des figures de moins d'une page. Les dessins doivent être postés à plat.

Les épreuves de *photographies* doivent être tirées sur papier glacé à gamme de ton étendue. Elles doivent être coupées, dressées et montées sur carton blanc, sans laisser d'espace entre celles qui sont disposées par groupes.

Les *épreuves en placards* sont adressées à l'auteur et il lui incombe de corriger toute erreur d'impression ou de contenu.

Cinquante *tirés à part*, sans couverture, sont fournis gratuitement. L'auteur peut profiter du renvoi des épreuves en placards pour commander des tirés à part supplémentaires. Les frais sont de $30.00 par page pour la publication des articles. Quand un auteur soumet un manuscrit, il doit spécifier que son institution accepte les frais.

LISTE DE CONTRÔLES POUR MANUSCRITS

Une attention particulière aux questions suivantes facilitera l'évaluation des manuscrits par les arbitres et les éditeurs.

Les découvertes, interprétations et conclusions sont-elles bien documentées et pertinentes au but de l'étude?

Les tableaux et figures sont-ils tous nécessaires et agencés pour faciliter les comparaisons? Y a-t-il contradiction entre les tableaux ou les figures et le texte, ou dans le texte même? Est-ce que certaines données devraient être présentées séparément, dans un rapport manuscrit ou dans un dépôt de données? Si vous faites une analyse statistique, la statistique cède-t-elle le pas à la biologie?

Le texte y gagnerait-il en clarté s'il était plus condensé, en tout ou en partie? Contient-il des exposés sommaires au début de chaque section ou paragraphe, et les détails de ces sections et paragraphes sont-ils pertinents au sujet traité? La marche du manuscrit est-elle conforme à la logique énoncée dans l'introduction?

Le *titre* est-il concis, tout en étant représentatif du contenu du rapport?

Le *résumé* donne-t-il l'essentiel des connaissances nouvelles?

L'*introduction* se limite-t-elle à une esquisse de la portée, du but et des raisons de l'étude? La revue de la littérature se limite-t-elle à la définition du problème?

La section *matériel et méthode* contient-elle le minimum de détails qui permettront aux autres scientifiques de saisir les grandes lignes de l'étude et de juger de la valeur des données?

Les généralisations sur les *résultats* sont-elles adéquates? Permettent-elles de distinguer entre constatations et déductions?

La *discussion* est-elle limitée à l'interprétation et à l'évaluation des découvertes?

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Guide for Typists Preparing Copy

Read "Guide to Authors" in the current volume of the *Journal*. When in doubt about how to type or arrange details, follow *Journal* practice.

Type the manuscript on white bond paper, not flimsy, preferably size 21.5 × 28 cm (8.5 × 11 inches). If possible, use paper with the lines numbered in the margin. Leave all margins at least 2.5 cm wide.

Double-space all parts of the manuscript, including tables, captions for illustrations, footnotes, and the reference list. Underline only material that is to be printed in italics. Indent the first line of each paragraph in the text and of each footnote.

In titles and headings, capitalize only the first word and proper names and adjectives. For small capitals, use small letters.

Indicate all text footnotes by superscript arabic numerals. Number them consecutively throughout the manuscript, starting with those on the title page. Place each footnote immediately below the reference to it, separating it from the text by horizontal lines.

On the first page type only the title, the authors' names and affiliations, related footnotes, and the running head (see Appendix A). Type the abstract on a separate page (see Appendix B). Number all pages, beginning with the title page and including those for tables and captions for illustrations.

Have the author check the finished manuscript, and send the ribbon copy and another clear copy to the Office of the Editor.

Tables: Examine the current volume of the *Journal* to see how tables are set up (see Appendix C). Note especially the following concerning *numbered tables:*

Type each on a separate page, using paper without the lines numbered. Number them with arabic numerals.

Use horizontal lines above and below the headings and below the columns, and seldom elsewhere. Never use vertical lines; leave extra spaces instead.

Indicate table footnotes by superscript small letters and type them below the table.

Place the tables after the list of references.

Where each table is first referred to, type in the margin "Table — near here."

Note that *text tables* are not numbered, are typed with the text, and seldom need horizontal lines (see Appendix C).

Illustrations: Send the *original* and two clear copies of each illustration with the manuscript. At the lower left of each figure and copy, give the author's name and the figure number. Also, type each caption with its figure for identification. For photographs, type this information on a strip of paper and fasten it to the back of the print. Do not write or type on the print itself. Also, type the captions in succession on a separate page, headed "Captions for illustrations." Put this page at the end of the manuscript.

Where each figure is first referred to, type in the margin "Fig. — near here."

Mathematical Expressions, Equations, and Formulas: Leave three spaces above and below lines that have much material in superscripts, and above and below equations and formulas. In the various expressions, place each component in its correct position (see Appendix D).

Show all symbols clearly. In the margin, spell out Greek letters the first time they occur, and distinguish between the small letter $\underline{l}$ and the numeral *one*, and between the capital letter $\underline{\overline{O}}$ and the numeral *zero*. Make other explanatory notes similarly.

References: Check the text to see that all references in the list are referred to. Type the reference list, double-spaced, in the style used in the *Journal* (see Appendix E). Names of journals are abbreviated as in the *Biological Abstracts* list; if an abbreviation is in doubt, type the name in full.

Spellings: About 100 words common in fisheries journals are listed in Appendix F.

Appendices: Appendices A to F are available on request from the Office of the Editor.

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Guide pour les secrétaires d'auteurs

Lisez le "Guide des Auteurs" reproduit dans l'édition courante du *Journal*. Si vous avez des doutes sur la façon de dactylographier le texte ou d'en agencer les détails, suivez la pratique du *Journal*.

Dactylographiez le manuscrit sur papier blanc de bonne qualité, et non sur papier pelure, mesurant de préférence 21.5 × 28 cm (8.5 × 11 pouces), laissant toujours une marge d'au moins 2.5 cm. Si possible, employez un papier avec lignes numérotées en marge.

Tout le manuscrit, y compris tableaux, légendes de figures, renvois et références bibliographiques, devra être dactylographié à double interligne. Ne soulignez que les mots qui devront être imprimés en italique. Mettez en retrait la première ligne de chaque paragraphe du texte et de chaque renvoi.

Dans les titres et les en-têtes, n'employez la majuscule que pour le premier mot et les noms propres. Pour les petites majuscules, employez les minuscules du dactylographe.

Indiquez tous les renvois du texte par des chiffres arabes suscrits. Numérotez les renvois consécutivement par tout le texte, à commencer par ceux de la page titre. Placez chaque renvoi directement sous sa référence, le séparant du texte par des lignes horizontales.

La première page ne doit contenir que le titre de la publication, le nom et l'affiliation de ou des auteurs, les renvois appropriés et le titre courant (voir Appendice A). Dactylographiez le résumé sur une page séparée (voir Appendice B). Numérotez chaque page, à commencer par la page titre, et y compris celles qui contiennent les tableaux et la légende des figures.

Voyez à ce que l'auteur vérifie le manuscrit final, et soumettez la première copie et une seconde copie suffisamment claire au bureau du Directeur de la publication.

Tableaux: Consultez une copie du *Journal* pour la composition des tableaux (voir Appendice C).
Portez une attention particulière à ce qui suit au sujet des *tableaux numérotés*.

Dactylographiez chaque tableau sur feuille séparée, vous servant de papier sans lignes numérotées.

Numérotez les tableaux en chiffres arabes.

Tracez des lignes horizontales au-dessus et au-dessous des en-têtes et au-dessous des colonnes, rarement ailleurs; ne tracez jamais de lignes verticales; laissez plutôt des espaces supplémentaires.

Indiquez les renvois dans les tableaux par des minuscules suscrites et placez les renvois au bas du tableau.

Placez les tableaux à la suite des références bibliographiques.

A l'endroit où le tableau est mentionné pour la première fois, indiquez dans la marge "Tableau — près d'ici."

Remarquez que les *tableaux dans le texte* ne sont pas numérotés, sont dactylographiés avec le texte et ne requièrent que rarement des lignes horizontales (voir Appendice C).

Figures: Expédiez avec le manuscrit le *dessin original* et deux copies propres de chaque figure. Au coin inférieur gauche de chaque original et copie, inscrivez le nom de l'auteur et le numéro de la figure. De plus, annexez à chaque figure la légende qui lui est propre, pour fin d'identification. Dans le cas de photographies, dactylographiez l'information sur une lisière de papier que vous collerez au dos. N'écrivez pas à la main ou à la machine sur la photographie même. En plus, dactylographiez les légendes, dans l'ordre, sur feuille séparée, intitulée "Légendes des figures." Intercalez cette feuille à la suite du texte.

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Equations, formules et expressions mathématiques: Laissez trois espaces au-dessus et au-dessous des lignes renfermant des chiffres ou des lettres suscrits et souscrits, ou encore au-dessus et au-dessous d'équations et de formules. Placez chaque composante des différentes expressions dans la position qui lui est propre (voir Appendice D).

Indiquez clairement tous les symboles. Epelez en marge les lettres grecques, la première fois qu'elles apparaissent. Faites une distinction entre la lettre l et le chiffre *un*, et entre la majuscule O et le chiffre *zéro*. Insérez de la même façon toute autre note explicative.

Références: Vérifiez le texte afin de vous assurer que toutes les références apparaissant dans la liste bibliographique sont bien mentionnées dans le texte. Dactylographiez à double interligne dans le style en usage dans le Journal (voir Appendice E). Les noms de revues sont abrégés suivant les *Biological Abstracts;* en cas de doute, écrivez le nom au long.

Orthographe: Une liste d'environ 100 mots communément employés dans les périodiques sur les pêches est donnée en Appendice F.

Appendices: On peut se procurer une copie des Appendices A à F sur demande au bureau du Directeur de la publication.

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Journal of the Fisheries Research Board of Canada

Volume 30, No. 12, Pt. 1
December 1973

JFRBAK30(12,1)1771–1920(1973)

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Diel and annual cycles of net plankton photosynthesis in Lake Ontario **G. P. Harris** 1779–1787

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Journal OF THE Fisheries Research Board OF Canada

Volume 30, No. 12, Part 2 of 2 Parts, December 1973

Technical Conference on Fishery Management and Development
Conférence technique sur la gestion et le développement des pêches
Conferencia técnica sobre administración y desarrollo pesqueros

Environment Canada Environnement Canada

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The *Journal* is devoted to original research papers and notes concerning aquatic organisms or environments relevant to Canada. Review articles that are critical appraisals of broad areas of research are also welcomed. Submissions in English or French are accepted without limitations as to origin, but must not have been published or copyrighted. Details on submissions are given in the guides to authors and typists at the back of this issue. Reprints of the guides are available free from the Office of the Editor.

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EDITOR'S FOREWORD

This special issue of the Journal of the Fisheries Research Board of Canada is devoted to the proceedings of a Technical Conference on Fishery Management and Development, organized by the Food and Agriculture Organization of the United Nations. The Conference was held in Vancouver from February 13 to 23, 1973. Experts and observers nominated by their governments attended the 9 days of sessions. The Conference objectives were: To centralize worldwide experience in fishery management and development, especially recent information; to exchange technical, scientific, and economic information on fishery management and development, and to receive accounts of successes and failures as guides for future action; to anticipate problems of overexploitation and means of reversing damaging trends; to identify opportunities and trends in fishery development; to consider where international cooperation in these matters is possible, and to provide guidelines for future FAO programs.

Three categories of papers were prepared for the Conference. Specialists were invited to prepare Review and Subject papers, and a general invitation was issued for Contributed papers. Copies of these were distributed to participants prior to the Conference in English, French, and Spanish.

The Conference was presided over by the General Chairman, Dr A. W. H. Needler, and the technical sessions by chairmen who are named in this proceedings. The order of procedure was as follows: authors of Review papers summarized the main points of papers submitted for the particular session. Authors of Subject and Contributed papers then commented briefly, followed by members of a preselected panel and other participants. A Session Report was drafted by the rapporteurs, Dr W. E. Ricker and Dr E. P. Weeks, and the session chairman, with assistance from other Conference delegates. The draft reports were distributed, and finally amended and adopted by the Conference, before the Recommendations were approved.

Drs Ricker and Weeks also acted as Special Editors of the Conference papers. Authors were allowed to revise their papers in the light of the discussions, prior to publication of this record.

The Journal of the Fisheries Research Board of Canada is privileged to publish this important collection of papers, under the joint sponsorship of FAO and the Fisheries and Marine Service of the Department of the Environment of Canada.

J. C. STEVENSON
Editor and Director of Scientific Information

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PREFACE

This collection of the papers prepared for the FAO Technical Conference on Fishery Management and Development (Vancouver, February 13–23, 1973) constitutes one of the most important results of that endeavor, and one that is of special value at this time.

As Dr. A. W. H. Needler, the General Chairman of the Conference, has pointed out in his summary of the highlights, the pressure on fishery resources in the world is already intense and it will become more so. With demand continuing to increase, the need to get the best of the resources, to increase the supply as far as possible, also becomes greater.

It is clear then that if world fisheries are to contribute as fully as possible to nutrition, employment, incomes, and human well-being in general, they will have to be carefully and effectively managed and developed. Besides an adequate legal and political framework (under intensive discussion in the United Nations and elsewhere) and besides wisdom and determination on the part of those responsible (for which we can only hope), this will preeminently require adequate technical knowledge and competence by those who are to design and implement management and development measures.

For these, the present collection will be a unique source of information and inspiration, bringing together as it does the thoughts and experience of more than eighty among leading fishery scientists and others professionally concerned with fisheries.

By publishing this collection and thus making it widely available, the Government of Canada through the Department of the Environment, and its Journal of the Fisheries Research Board of Canada, is rendering a signal service to the world fishery community. We must all be grateful to them.

F. E. Popper
Assistant Director-General (Fisheries)
Food and Agriculture Organization of the United Nations

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FAO Technical Conference on Fishery Management and Development

OPENING SESSION

GENERAL CHAIRMAN
A. W. H. NEEDLER

Managing Our Oceans for Mankind[1]

HON. JACK DAVIS, P.C., M.P.

Condensation of Opening Address

The Minister emphasized the importance of the Conference in view of the need to maintain and protect marine sources of food essential for an increasing world population. Evidences of overfishing and injury to stocks in many major fisheries point to the urgent need for international cooperation in management practices. Limits to growth of fisheries must be established for economic reasons as well as for conservation and efficient use of living resources of the seas. Scientists will have to provide the basic biological information on each species, governments must make and apply internal and international control measures, and economists indicate the optimum sustainable economic yield. This is the challenge that faces the Conference.

Le ministre a souligné l'importance de la Conférence vu le besoin de conserver et protéger la mer comme source d'alimentation pour un monde de plus en plus peuplé. Certaines pêcheries sont surexploitées ou endommagées et pour remédier à ces problèmes, il faut une action de gestion sur le plan international. Il faut limiter l'expansion des pêches pour des raisons économiques, pour assurer la conservation et pour garantir un emploi optimal des ressources de nos océans. Les scientifiques recueilleront les données biologiques sur les diverses espèces de poissons, les gouvernements devront prendre des mesures de contrôle à l'échelle nationale et internationale et les économistes auront à fixer le rendement soutenu maximal. C'est le défi que doit relever cette conférence.

El Ministro hizo hincapié en la importancia de la Conferencia, dada la necesidad de mantener y proteger las fuentes marinas de alimentos esenciales para una creciente población mundial. La evidente pesca excesiva y daños a las especies en numerosas importantes pesquerías muestran la necesidad urgente de la cooperación internacional en prácticas administrativas. Se deben establecer límites al crecimiento de la pesca, tanto por razones económicas como para conseguir la conservación y uso eficiente de los recursos vivientes del mar. Los científicos deberán proporcionar la información biológica básica de cada especie, los gobiernos deberán dictar y aplicar medidas de control interno e internacional, y los economistas deberán indicar el mejor rendimiento económico sostinedo. Este es el reto con que se encara la Conferencia.

Welcome to Canada. Welcome to an ocean frontier where strenuous efforts are being made to manage the living resources of the sea in such a way as to benefit, not only ourselves, but the rest of mankind.

This is an auspicious gathering. This conference, sponsored by the FAO, and indirectly by the United Nations, can make history. It is tackling a problem that has baffled fishermen for years. It is also trying to find answers to the question of how man, in his mounting numbers, is going to feed himself and at the same time preserve the marine environment in its natural state. We are talking about billions of people: 4 billion now, 8 billion in the year 2000. We're also talking about 70% of the total area of the world, more than two-thirds of which is covered with salt water.

There are limits to growth and to the human population which our planet can sustain. One of these limits is the productivity of the sea. Most of the ocean expanse is a comparative desert, barren of sea life. The rest, less than 20%, can be overfished. Many more productive areas are being overfished — being stripped of their best stocks. The end of an era of easy exploitation is definitely in sight.

When the world's first fisheries management conference was held in 1955, the global catch was 25 million metric tons. Now it is 70 million metric tons! But there are warning signs on the horizon. Fisheries scientists say that we'll be lucky to hit the 100 million ton mark by 1980, and that total figure may be all that the living resources of the sea can stand. It may be the highest figure that our combined fishing fleets can reach without, at the same time, doing irreparable harm to fisheries the world over.

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

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The concept of "limits to growth" is being widely touted these days: it is a symbol to some, it has real meaning for others. It is becoming meaningful indeed to those who are fishermen or whose livelihoods depend on the health of the living resources of the sea. For those who are in, or associated with, the fishing industry, there is one ultimate reality. The 100 million metric ton ceiling is there, plus or minus 20%, and it's closer than many another limit which mankind faces today.

True, we can take a greater quantity of fish from the sea for a few years, but we can't go on increasing fishing effort and expect an ever-rising number of fish to enter our nets. They aren't there in the first place. And they certainly won't be there in 100-million-ton numbers if we continue the "let's fish and get out" practices that fishing nations have been pursuing thoughtlessly, greedily, through the 1950s and 1960s.

There is a limit to the total tonnage of fish which we collectively can take from the sea, and we can hit it before we have a global plan, to deal with biological, physical, and economic limits.

So we must make haste, together. We must plan ahead, together. We must lay down rules that will help not only to maximize the tonnage of fish from the sea, but also to ensure that its unique species, its diveristy, its resilience, indeed its magnificence, is preserved forever.

I have identified an outer limit in physical terms, but there is also the qualitative aspect. I mean variety, a limit for each species. Each species in its own area has its own limit, which must not be exceeded for any length of time. So there are many lesser limits, or quotas if you like, which equate to the optimum sustainable yield in a given area for every species of fish. Some are already in trouble in significant numbers and in many parts of the world. Some well-known species have already been overfished heavily — herring in the North Sea, for example, or pilchards off the California coast, or sardines in the Mediterranean. Whether by greedy fishermen or poisoned by pollution, they seem to be on their way to extinction unless we collectively do something about it, and soon.

Danger signals are flying everywhere. Whales, at the top of our living resource pyramid, have been in trouble for years. The lively salmon has all but disappeared in the North Atlantic. Cod catches are at, or beyond, their maximum sustainable yield and other bottom fish, like halibut, are on the verge of becoming endangered species.

These facts reinforce something I said earlier . . . we have a series of "limits to growth," related often, but each must be dealt with largely in its own way. The techniques of management, of conservation, sustained yield, and efficient utilization may be similar, if not the same. It is for a further explanation of these concepts and these techniques that we look to you today.

Obviously, something has to be done. Someone has to look at an entire stock of fish and work out a level of cropping that can be sustained decade after decade. It falls to governments to draw up the rules, and to enforce them. But cooperation between national governments is essential. Boundary lines often cut across the natural habitat of living resources. Fish are no exception, the seas already having been cut up, unnaturally, by territorial limits and fishing lines of one kind or another.

We must ask the biologist where each species of fish tends to move during the course of its lifetime. If it is out over the Continental Shelf, then the Continental Shelf becomes the right area of management for that stock. If it is in a major bay or inlet, then the bay or inlet becomes the laboratory. If it is an entire ocean, then the ocean as a whole becomes the arena in which the management process for that particular species takes place.

What I am saying is that the laws of nature should take precedence; to make the most of nature's gifts, we will be wise to study her ways. To make the most of the living resources of the sea, we will be wise to co-operate internationally much more than we have.

We have learned a lot since our first meeting on fisheries management in the 1950s. We have seen international commissions established to protect, conserve, and upgrade local fish stocks: they have done research; they have set quotas and have reduced waste; they have helped to streamline fishing fleets, and have sometimes increased their profitability.

Some stocks are recovering. Others are being cropped on a true, sustained yield basis. Fewer vessels are chasing more fish. Incomes are rising in these areas and the market outlook is better than before. But biological parameters are not enough. We must pay some attention to economics as well.

Many of you know that the economic safety valve usually blows before the biological or physical one does. Knowing all of the financial and social facts of life, we would stop our headlong rush towards extinction before and not after we reached what fish population dynamics experts call the "maximum sustainable yield." We'd taper off fishing effort when we approached the "optimum sustainable economic yield."

This would leave more fish in the sea. It would also put the accent to a great extent on variety. Of course, it would also mean fewer boats and fewer fishermen, but this, together with a higher income per individual fisherman, is what fisheries economics is all about.

The fishing industry in Canada is looking up. Prices are rising and more operations are being carried out on a sustained yield basis. We have fewer fishermen and fewer fishing vessels than we had in the 1960s, but the fishermen are better off and our resources are being protected as never before. Thanks to the efforts of our scientists, thanks to the cooperation that we have received from neighbors in the United States and across the Pacific in the USSR and Japan, we have been able to maintain our catch of salmon in quantitative terms; salmon runs, in total, are about the same as they were in the 1920s. Herring are coming back, groundfish stocks are in good shape.

We have done a lot of research and we have a great story to tell. But, like you, we also want to listen to your experiences, your ideas, your plans for the future. We can learn from you and we hope you will be able to learn something from us. That is what this scientific conference on the wise management of the living resources of the sea is about.

Whether we be scientists or fishermen, whether we be from near or far, we have a job to do here in Vancouver. It is an important job, a challenging task. Our aim is conservation, in the widest sense of the word. It is a concept that recognizes real limits to growth on one hand, and the many opportunities we have to upgrade our fisheries on the other. I know you are equal to this task. We will all be watching your deliberations. May I, on behalf of Canada and of people everywhere, wish you well in your endeavors.

Keynote Address[1]

F. E. Popper

Assistant Director-General (Fisheries), FAO

The contribution made by Canada in providing the means for the Technical Conference was gratefully acknowledged, and the terms of reference were summarized as approved by Council of the FAO. Briefly, these are — to discuss the scientific and technical means of solving problems and reaching objectives in fisheries management and development. Significant problems that have become evident since the UN Conference in 1955 are: an urgent need for management of most of the traditionally fished stocks; decreasing rate of growth of the world fish catch in the face of increasing demand; economic interactions from greatly intensified fisheries and fishing enterprises; importance of development in relation to management. The need to take the long view in approaching these problems was emphasized, as well as the great value to be derived from recognition of existing deficiencies in organizations or methods. Universally acceptable rules for control of fisheries, and participation by all nations in supplying fisheries data esssential for efficient management, are obvious requirements of high priority.

Monsieur Popper remercie le Canada de s'être fait l'hôte de la Conférence et résume le mandat de la Conférence tel qu'il avait été fixé par le conseil de la FAO: traiter des moyens scientifiques et techniques de résoudre divers problèmes et fixer certains objectifs de gestion et de développement des pêches. Quelques problèmes qui se sont posés depuis la réunion de l'ONU en 1955: le besoin urgent de gérer les stocks les plus exploités; la baisse des prises sur le plan mondial malgré la hausse de la demande; les effets économiques de l'intensification de l'effort de pêche; l'importance du développement par rapport à la gestion. Monsieur Popper a souligné qu'il fallait aborder ces problèmes en pensant surtout à l'avenir. Il a dit qu'il était très salutaire de savoir reconnaitre les faiblesses des méthodes ou organisations actuelles. Il est de toute première priorité d'adopter des règles universelles en matière de pêches ainsi qu'un régime de rassemblement des données auquel participeraient tous les pays du monde en vue de faciliter la gestion.

Se agradeció la contribución canadiense para proporcionar los medios necesarios para la conferencia técnica y se resumieron las facultades aprobadas por el Consejo de la FAO. Brevemente, éstas eran — debatir los medios científicos y técnicos para resolver problemas y alcanzar objetivos en la administración y desarrollo pesqueros. Los problemas importantes evidenciados desde la Conferencia de las Naciones Unidas de 1955 son los siguientes: la urgente necesidad de administrar la mayoría de las especies pescadas tradicionalmente; crecimiento reducido de la captura mundial de pescado frente a la demanda creciente; interacciones económicas de pesquerías y empresas pesqueras altamente intensificadas; importancia del desarrollo en relación con la administración. Se hizo hincapié en la necesidad de adoptar una perspectiva larga al enfocarse estos problemas, así como el gran valor derivado del reconocimiento de las deficiencias existentes en organizaciones o metodos. Las reglas de control de la pesca aceptables universalmente, así como la participación de todas las naciones en el suministro de datos pesqueros esenciales para una administración eficiente, son requisitos obvios de gran prioridad.

It is with great pleasure and with some misgivings that I deliver the keynote address to this Conference. My first task, however, is entirely pleasurable. It is to express, on behalf of the Director-General of the Food and Agriculture Organization of the United Nations, the deep appreciation and gratitude of our Organization for the kindness and generosity of the Government of Canada in inviting us to hold this Conference in this country, in providing not only all the necessary facilities in an exemplary fashion, but also funding most of the expenses which would normally fall on FAO, and beyond that, in making extra funds available to cover the cost of travel and attendance for selected participants from developing countries. Our thanks are due also to the development assistance authorities of Denmark, Norway, Sweden, and the United States of America who have each enabled some participants from developing countries to attend.

This Conference had to be convened at what, for so sizable an undertaking, was extremely short notice. It is only 10 months since the FAO Committee on Fisheries recommended the holding of this Conference,

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

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and only a little more than 2 months since the Council of FAO formally authorized it. This has meant, necessarily, that the preparatory work had to be done under heavy pressure and that authors of papers had to meet extremely short deadlines. We therefore owe them our special thanks for the fact that we are able to start this Conference with a remarkably complete set of papers.

Let me conclude this first part of my address by saying — and I am sure I speak for all participants in the Conference — how happy we are to have been welcomed so warmly in this beautiful city and how much we look forward to meeting the people of British Columbia, who have so hospitably invited us through their Provincial Government and through their Fisheries Association. May I add one personal remark: I am most grateful to those who have made it possible for this Conference to be held here, where I began my association with fisheries almost 25 years ago. This is for me a sort of silver jubilee and I am delighted to celebrate it in the company of so many old and new friends. It is a special pleasure for me do do so under the chairmanship of Dr Needler, as it has been my privilege to work with him over these 25 years.

Returning to my role as spokesman for my organization, I turn to the mandate given to this Conference. This took the form of a decision by the Council of FAO, acting on a recommendation by its Committee on Fisheries, known as COFI. The Council agreed that this Conference "could make a substantial contribution to the spreading of knowledge and experience in fishery management and development which would assist all countries in making optimum use of the valuable living resources of the oceans and inland waters."

All those contributing to the Conference must have this well in mind — their contribution being in the nature of assistance needed in order that better use be made of the resources of the waters. The purpose of the Conference coincides with that of much of the regular work of FAO staff, and we gladly join our efforts with yours.

In authorizing the Director-General to convene this Conference, the Council adopted terms of reference and reporting procedures suggested by COFI (set out in Technical Session II in the paper by M. A. Robinson, p. 0000). We are to consider scientific and technical principles and methodology, together with the state of the resources, their exploitation, management mechanisms and requirements, as well as perspectives for fishery development. But these topics must be considered without going into political aspects, or problems of jurisdiction, or rights over fisheries and similar matters; and as regards economic matters we are instructed to consider them only insofar as they relate to the problem of making fisheries profitable and not as they relate to social or to political problems.

These instructions are explicit though they may appear difficult to follow strictly, but none of us must be deterred by these apparent difficulties. Certainly, the Director-General and those who act for him on this occasion have to abide by these instructions. They do not require us to deny that problems of fishery management and development have political aspects or that problems of jurisdiction are not relevant to them, but ask us to take them for granted. The experience of FAO in offering scientific and technical information to the Sea-Bed Committee of the United Nations General Assembly has convinced me that the matters we have before us can be discussed quite well, without becoming involved in their political aspects or problems of jurisdiction. This is not difficult but merely requires care and restraint. I am sure that we can count on the good will of all participants to keep matters that are outside our terms of reference out of our discussions, as they must certainly be kept out of our reports. If we do this, we will not make our discussions any less fruitful or our conclusions less applicable.

On the contrary, the more I learn of the problems of fishery management and development in different parts of the world, under different political and economic systems, and different jurisdictional regimes, the more am I impressed with the similarity of the problems rather than with their diversity. While political and economic objectives may vary, the scientific and technical means of reaching them are mostly similar if not identical, and it is these means that we are here to consider. Allow me to suggest that by observing our limitations we will make our discussions and conclusions more universally relevant and therefore perhaps more valuable.

We should also remember that this Technical Conference is by no means the principal international forum for the discussion of problems of fishery management and development. There are many others where the same problems are being considered in different contexts, with different emphases and for different purposes. I have already mentioned two, COFI and the Sea-Bed Committee acting as a preparatory committee for the United Nations Law of the Sea Conference — the latter primarily concerned with those aspects of our subject matter that are outside our terms of reference. Then there are the so-called regulatory international fishery bodies, regional and otherwise, concerned with the conservation of the human environment as a whole — and yet others. How then are we to see our work in relation to theirs? Not, I think, as marginal or merely preparatory. Unlike most of the bodies mentioned, we cannot make decisions or commit governments; but our strength and the importance of this Conference lie in the fact that, while we are free of the constraints of government delegates, we have at our disposal the most remarkable range of expertise in the technical and scientific aspects of our subject ever assembled and are able to concentrate on these aspects as they appear against a background of actual experience extending across the world. This presents us with a tremendous challenge to make a most important, a unique contribution to the solution of the problems with which those responsible for fisheries management and development are faced.

To come back to the instructions given by the Council of FAO, as this is a meeting "to deal with technical and/or economic matters attended by experts designated by Member Governments and by observers from Member Nations, non-Member Nations and intergovernmental and international non-governmental organizations having established relations with FAO, the participants would not be expected to take decisions on behalf of the government that has designated them."

Technically speaking, the participants are divided into experts and observers (cleared or designated by governments or international organizations) and FAO staff. The distinctions between these categories are not practically important, and I hope you will all participate fully in the work of the Conference, so as to bring to bear your wide range of knowledge, experience, and backgrounds. Nor need I say much about the officers of the Conference. The presence of so much talent will clearly make the General Chairman's important task most rewarding, though hardly easy. We are extraordinarily fortunate that he has agreed to undertake this job and to put at our disposal his unparallelled experience and ability as well as all those personal traits that have made him so effective and so well appreciated in similar roles in the past. He will have competent help from the distinguished persons who have responded to our invitation to serve as session chairmen or on the steering committee.

Responsibility for the arrangements and running of the Conference rests on the Secretary. His task has been and is particularly difficult because of the almost impossibly short deadlines to which we had to work. Again we have been lucky to have secured the services of a man with the right kind of experience and a willingness to dedicate himself entirely to the job, and an ability to get the fullest cooperation from the many people, mostly on the staffs of the Government of Canada and of FAO, whose contributions are essential to the success of the Conference. The Canadian Government has also designated a Liaison Officer who fully matches the Secretary's qualities. I am much impressed by the way the preparations for the Conference were made, but will say no more about them at this time. Nor will I try to describe arrangements for the discussions and the reporting on them. As the representative of the Director-General of FAO, it is my duty to ensure that his responsibilities are properly discharged; the most important ones I have already mentioned. I hope, however, to be allowed to make a small contribution to the discussion as if I were here as one of the participants.

Now let me deal with some other important matters. While I will not anticipate the substance of the discussion, I must say something about the objectives of the Conference and the outcome one might envisage for it. Logically, I should do this with reference to the present situation in fishery management and development, described in the papers before you. But this is neither necessary nor is there time.

Since the problems before us were considered in the UN Conference of 1955, great changes in world fisheries have taken place. Many of these are obvious, but their implications and the solution of the problems which they have created are often far from clear. Mr. Davis has already most professionally described some of these changes and problems, but let me mention some that seem particularly significant. Firstly, in 1955, management was an immediate problem for only a limited number of fisheries and stocks, and fishery development in developing countries was only beginning. Today most of the traditionally fished stocks and quite a few others are in need of management, some in urgent need. Many developing countries are intensely interested in expanding their participation in world fisheries and some have already become significant participants. In doing this, developing countries encounter special problems in reconciling the establishment of modern fishing industries with the improvement of their prevalent artisanal fisheries. Secondly, the rapid growth of the world fish catch is faltering at a time when world population demands more protein food from the sea and inland waters. Thirdly, what seemed a series of separate problems concerning individual fisheries has become a system of interconnected problems, both through the physical interaction of greatly intensified fisheries and through the economic interaction of the activities of fleets and fishing enterprises, as well as of the restraints imposed on them by management regulations. Some of us discern the incipient interaction problems between fisheries and other uses of the oceans that might in time resemble the corresponding serious problems of inland fisheries. Pollution in particular is causing increasing concern. Lastly, in 1955 one was inclined to consider management (or conservation, the aspect on which interest was then focused) as separate from development — with comparatively little attention given to the latter. Today, there is a much wider view that management and development must not be thought of separately; conservation is increasingly seen as a subsidiary objective — except as regards species in danger of extinction, one of several factors that can be important in development.

I believe that it will be right for us to bear this last point in mind throughout our discussions, and also to remember that it is development at which the policies and aspirations of countries — particularly in the developing world — tend to aim. In the language of economists, this comes out as maximizing the national share of the yield of the resources accessible to the country in question — not necessarily the physical yield. What is to be maximized depends on general policies adopted by governments (which we are to take for granted here). It might be food, it might be income, it might be employment, or yet other things. For particular groups, it might be foreign exchange, or some less tangible value such as national prestige, the preservation of a way of life, or what you will. What we are concerned with are the means by which any general aim could be achieved more effectively through the management and development of fisheries.

To make our discussions of practical value, we must look into the future and assess its possibilities, in the light of what we know about the situation. The questions we should ask in this assessment should be concrete and pointed, so that the answers will be directly helpful to those who should take action in the future.

Let me give some examples of questions the Conference could ask: what are the main technical factors hindering fully effective management and development? what is lacking in dealing with these factors — information, methods, expertise, communication, application, finance? who can do something about these things? what sort of cooperation is needed? what are the chief opportunities for development? where are the main danger areas for resource management?

Let me finally say what I think the outcome of this Conference might be. One thing is obvious. The Conference has already resulted in bringing together information, experience, and ideas in the papers before us which in themselves are a considerable contribution to the improvement of fishery management and development. It is also clear that discussion — both formal and informal — within so large and so highly qualified a group will of necessity at least stimulate and clarify thinking about the problems: it will give us an increased awareness of these problems and of possible solutions. Discussion will also, I expect, give us a better understanding of what fisheries management and development will mean in a world where the need for making use of the resources is becoming much more pressing, where new resources must be brought under exploitation or created, where fisheries can develop so rapidly that traditional methods of management may be ineffective and where newcomers to industrial fishing will seek growing shares. Perhaps the discussions will also lead us to a fuller realization of deficiencies in methods and institutions, and of promising developments which can remedy these deficiencies. If we achieve these things, we will have been well justified in the investment of time and effort in the holding of this Conference.

But we might be more ambitious still. One can perhaps hope that out of our discussions there will emerge some answers that will have at least fairly wide application and will serve as general principles and criteria to guide those responsible in governments and international organizations and in the fishing industry itself in improving management and promoting development. There may also be agreement on specific steps that should be taken to remove certain obstacles to more efficient management and development.

To give you examples of what I have in mind, could we not propose some general rules that should be followed by all participating in a fishery, individuals or industrial firms or countries, no matter whether the fishery takes place within the jurisdiction of a single government, of several, or outside it? Could we not say something about the minimum contribution that should be made by all participants to the supply of statistical and other data necessary for effective management, something about what they should contribute to scientific research? Can we perhaps say something about when management measures should be taken, or on what kind of evidence? On the other hand, are there some general rules we can propose to avoid wasting harvestable resources through unnecessary or inappropriate regulations? Is there any general advice we can offer about speeding fishery development in developing countries, through, for instance, better participation by industry from developed countries? I do not know how far we will get with this kind of question, but I do hope we will attempt them at least.

We have before us 2 weeks that present us with a great opportunity. We have to deal with problems that are important and urgent. We have among us all the qualifications to tackle them successfully. Actual success will depend much on our approach to these problems and on our attitude to each other. If we concentrate on what we have in common, if we stick to the essential problems and not let ourselves be diverted by marginal questions, if we are ready not only to put forward our own ideas and experience, but to learn from each other and to respect each other's views and arguments, we can count on success. Then we will be able to look back to this Conference as a major contribution to future fishery management and development.

FAO Technical Conference on Fishery Management and Development

TECHNICAL SESSION I

Scientific Basis and Methodology for Management and Development of Fisheries

CHAIRMAN: B. DIOP, SENEGAL

Objectives and Problems of Managing Aquatic Living Resources[1]

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In the management of aquatic living resources a wide range of objectives has emerged, associated with maintenance of renewable resources at productive levels, socioeconomic goals, and national and international political interest. Conservation objectives are largely concerned with "rational use" concepts, while socioeconomic goals may be associated with economic efficiency, resource development, allocation of resources between user groups, etc.

A number of problems confront managers of aquatic living resources. They include the rapidity of the changes occurring in fisheries, conflicting objectives, the fragmented and limited jurisdiction of management agencies, adequacy of scientific input into management decisions, difficulties of enforcement, and multiple use interest. Improved management of aquatic living resources will require decision-making machinery that is responsive to the dynamic character of modern fisheries, systems to resolve potential conflicts in human values, a commitment of governments, managers and scientists to assume the responsibilities delegated to them, including the promulgation and enforcement of appropriate regulations, and a recognition on the part of management that they cannot expect scientific unanimity or certainty regarding the status of fish stocks and the nature of the actions required to ensure their productivity. Although the responsibility to manage is clearly the mandate of the administrator, the scientific community has the responsibility to effectively communicate its findings to managers, to evolve methods of providing quick and reasonably cheap diagnoses of the status of stocks, and to contribute to the development of the theory and application of the total systems approach to management of renewable resources.

L'aménagement des ressources biologiques du milieu aquatique remonte aux commencements de l'histoire humaine. Toute une série d'objectifs se sont dégagés, liés au maintien des ressources renouvelables à des niveaux productifs, à des buts socio-économiques et à des intérêts politiques nationaux et internationaux. Aux fins de la conservation, on s'efforce surtout de définir des concepts d' "utilisation rationnelle"; par contre, dans le contexte socio-économique, on vise à la rentabilité et à la mise en valeur des ressources, on cherche à attribuer des parts aux différents groupes d'utilisateurs, etc.

L'aménagement des ressources biologiques du milieu aquatique se heurte à un certain nombre de difficultés. Parmi celles-ci: les modifications rapides intervenant dans les pêches; les objectifs antagonistes; la juridiction fragmentaire et limitée exercée par les organismes de réglementation; le niveau d'information scientifique requis dans les décisions relatives à l'aménagement; les difficultés d'application pratique; enfin, l'intérêt d'utilisations multiples. Pour améliorer l'aménagement des ressources biologiques du milieu aquatique, on aura besoin d'organismes directeurs qui tiennent compte du caractère dynamique des pêches modernes et de dispositifs permettant de résoudre les conflits possibles de valeurs humaines; il faudra aussi que les gouvernements, les responsables de l'aménagement et les chercheurs assument pleinement les tâches qui leur sont confiées, y compris la promulgation et la mise en vigueur de réglementations appropriées, et que les organismes directeurs prennent conscience de ce que, scientifiquement, il n'y a pas d'unanimité ou de certitude possibles quant à l'état des stocks de poissons et à la nature des initiatives requises pour en assurer la productivité. L'aménagement lui-même est de toute évidence le mandat de l'administrateur, mais la com-

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munauté scientifique a pour rôle de communiquer avec efficacité ses observations aux responsables, d'élaborer des méthodes permettant une diagnose rapide et relativement peu coûteuse de l'état des stocks et d'aider à la mise au point théorique et pratique d'une analyse globale des systèmes et à son application dans l'aménagement des ressources renouvelables.

La explotación racional de los recursos acuáticos vivos tiene su origen en los primeros días del hombre. Desde entonces han surgido muchas reglamentaciones relacionadas con el mantenimiento de la productividad constante de los recursos renovables, objetivos sociales y económicos e intereses políticos nacionales e internacionales. La conservación se ocupa ante todo de formular conceptos de "explotación racional", en tanto que las finalidades sociales y económicas guardan relación con la consecución de un rendimiento económico, explotación de los recursos, su distribución entre los diversos grupos que los utilizan, etc.

A los encargados de la reglamentación de los recursos acuáticos vivos se les plantean varios problemas que comprenden la rapidez de los cambios que ocurren en la pesca, los objetivos antagónicos, la jurisdicción fragmentada y limitada de los organismos encargados de la reglamentación, si las decisiones relativas a la reglamentación tienen una base científica bastante sólida, dificultades de hacer respetar las disposiciones e interés en los usos múltiples. Mejorar la reglamentación de los recursos acuáticos vivos exigirá sistemas para tomar decisiones que se adapten al dinamismo de la pesca moderna; para resolver los posibles conflictos de interés práctico; que los gobiernos, gerentes y científicos se comprometan a asumir la responsabilidad que se les delegue, incluida la promulgación de la legislación necesaria y que los responsables de la reglamentación reconozcan que los científicos no pueden ser unánimes ni estar seguros en lo que se refiere a la situación de las poblaciones de peces y la naturaleza de las medidas que se tienen que tomar para asegurar su productividad. Aunque es evidente que el administrador tiene la responsabilidad de la reglamentación, el científico la tiene de comunicar claramente sus conclusiones a aquél, de encontrar métodos para determinar rápida y económicamente la situación de las poblaciones y de contribuir a la formulación de la teoría del estudio sistemático de la reglamentación de los recursos renovables, y su aplicación.

FISHERIES management[3] has been described as including ". . . everything done to maintain or improve fisheries resources and their utilization" (Carlander 1969). Carlander's definition includes some areas not normally covered in the course of fisheries management – particularly with respect to biological objectives. For example, management may include fisheries development, i.e. exploratory fishing; gear, harbor, and fleet development; stock selection; environmental maintenance; processing; marketing; and establishment of aquatic reserves, parks, etc.

The time available has not been sufficient for an extensive review of all aspects of fisheries management. We have therefore summarized writings of many contemporary scientists and administrators regarding this subject. No attempt has been made to establish priorities on international objectives, for these vary from country to country, between ethnic groups, and by geographic areas. We have, however, attempted to clarify the problems, and have proposed concepts and actions which could improve the quality of management of aquatic resources and their environment.

Objectives of Managing Living Resources

Objectives in managing aquatic renewable resources have sprung from philosophers, fishery scientists, politicians, government institutions, and public attitude. It should come, then, as no surprise that proponents of conservation and socioeconomic interests have generated a variety of goals. In our discussion of this subject we have classified objectives into three groups: (1) those concerned with the maintenance of resources; (2) those which are of a socioeconomic character; and (3) those reflecting national and international political interests.

OBJECTIVES CONCERNED WITH MAINTENANCE OF RESOURCES

The concept of fisheries conservation and the possibility of managing fish stocks extends well back into man's history. Egyptian, Greek, and Roman literature demonstrate that various laws were enforced to control fishing activities and that fish farming was in existence long before the birth of Christ (Royce 1972). It is also apparent that man had become familiar with the impoverishment of fish supplies and that laws were enacted to replenish fish stocks. Originally, protection of fish stocks was frequently bound up with religious beliefs. For example, during the Ming Dynasty in China (1368–1643) it was considered a sin to catch mature fish of useful species, and apparently spawning areas were designated as sacred places by the ancient Prussians (Nikolsky 1956).

The history of fisheries conservation has been associated with mysticism (which has persisted to modern times), and the mysticism manifests itself in the functional techniques employed by some management agencies.

Although one can find universal support for "rational use of renewable resources" or for "conservation," the operational definitions, concepts, and principles of conservation depend on who talks about them (Royce 1965, 1972). Management related to maintenance of resources has many facets. It may be concerned with allocating and managing a given resource for the production of food or industrial products, or with using it for recreational purposes, or simply with its preservation for esthetic reasons.

In contrast to the preservationist, most fishery administrators and scientists regard aquatic resources as renewable, i.e. if the resource is not used, the surplus production is wasted. This concept has given rise to principles which allow a harvest of the excess over that needed to maintain the stock at a productive level. The population dynamicist has, in turn, expressed the theoretical surplus in terms of quantitative models which, given the proper inputs, provide several techniques for estimating the "maximum sustainable yield" (MSY). The models can be used to develop harvesting strategies which will yield the maximum surplus production from an aquatic living resource over an extended time frame, the MSY representing an average of the potential surpluses that might be produced from a population.

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[3] In a broad sense, we have considered the term "fisheries resources" to include the spectrum of the living resources which inhabit the aquatic environment.

It is noteworthy that ideological differences concerning forms of government prevail among nations of the world, but the aims of fisheries management (as broad biological objectives) seem to have international acceptance.

Nikolsky (1956), for example, states that one important management goal of the Socialist fishing industry is obtaining the maximum fish production; that is, not a maximum in a single year but repeated year after year. He further comments that this is the goal of industry, which gives rise to the scientific need to establish principles of fish population dynamics. These objectives do not differ much from those expressed by two United Kingdom scientists (Garrod and Clayden 1972) that "the concept of maximum sustainable protein yield is one objective which has proved part of the rationale for discussions of fishery conservation problems..."

They also appear similar to objectives stated by the Washington State (USA) Department of Fisheries (Anon. 1964): "The biological aim of fishery management is to attain the maximum continuing or sustained yield. Any number of fish beyond that needed for the replacement of the stocks is excess and should be harvested. It matters not (biologically) who harvests that fish providing the fishery does not reduce the replacement potential or is not harmful to a certain segment of the population (immatures, downstream migrants, etc.) and does not adversely affect the environment. The fish may be captured at anytime during their life span when they are of a desirable size or are in most valuable condition. This may occur in either the marine or fresh water environment."

In these discussions of conservation objectives, all authors (or agencies) recognize the necessity of dealing with socioeconomic implications of management.

The objective of maximizing protein production from the aquatic environment has produced a number of functional goals. For example, the concept of preventing waste is obviously an aim of many management institutions – the objective being to prevent during harvesting the destruction of plants or animals not desired by the harvester. They may be unwanted by the exploiter for social or economic reasons, but may have economic or esthetic value to other fishermen or nations.

Preventing environmental changes which degrade the productivity of aquatic life also has been a major objective of agencies managing these resources. This goal may be associated with the broad mandate of protecting and enhancing the environment. It includes activities such as habitat improvement: e.g. building of fish screens and fish ladders on streams and rivers; creation and maintenance of an environment which will enhance survival during certain stages of an animal's life history (artificial propagation, etc.); predator control; and creation of controlled environments which allow commercial farming of aquatic living resources (Carlander 1969, Royce 1972).

SOCIOECONOMIC OBJECTIVES

During the past two decades, increased attention has been paid to socioeconomic aspects of fisheries. Several facts emerge from the literature. There seems to be a consensus that socioeconomic objectives must play an important role in managing the harvest of fisheries resources; and socioeconomic goals are perhaps more variable and controversial than those established for conservation purposes.

Crutchfield (1965) has noted that the manifold economic problems affecting fisheries have been largely ignored by fisheries management with its straightforward pursuit of the largest possible yield, which may have magnified the economic problems. Crutchfield has repeatedly proposed that if the economic welfare of user groups is considered, the objective of maximizing net economic yield, i.e. catching fish at lowest possible cost, is as important as the maximum sustainable yield.

The economist argues that the objectives of fishing or fisheries management cannot be stated in terms of fish alone. The production of useful goods from the sea, like any other production, requires joint use of labor, capital, and natural resources; and in the simplest possible terms, the objectives are to maximize the excess of total value of yield over total cost.

Rothschild (1971) suggests that a suitable economic goal would be attainment of "economic efficiency." The term "economic efficiency," however, is not meaningful unless an operational definition is provided. Dorfman (1967) considers economic efficiency to include the efficiency of production and consumer sovereignty. He quoted the Panel of the Commission on Marine Science Engineering and Resources (USA) elaborating on this objective, which suggested as socioeconomic objectives: "... (1) that the marginal cost of production should just equal the marginal value of the project, (2) that the catch should be taken at the lowest possible cost, (3) that management should contribute to the invention of new fishing methods and their innovation, and finally (4) that the income from a fishery should be shared by the participants in the fishery and should be no worse than the incomes earned in other activities."

These goals undoubtedly are objectives that fisheries managers could follow but they are perhaps idealistic. Broadly stated objectives (e.g. efficiency, or attempts to achieve better distribution of income) do not provide management agencies with guidance as to specific goals or how to achieve these optima. From the point of view of fishermen and processors who might benefit from the resources, Rothschild (1971) feels that the most immediate goal might be reasonable wages and a reasonable return on investments.

A report on economic aspects of fisheries management (prepared by FAO as a result of a meeting of biologists and economists in Rome in 1965) stated that there are generally accepted criteria for good economic performance, which apply to fisheries and other industries. Simply, the objective is use of all resources for maximum net economic yield.

It is evident that one socioeconomic objective or a set of such objectives need not apply equally to all nations, or even to all regions within a nation. Marr (1972) notes, for example, that one such goal might be maximum employment opportunities. In more affluent countries, objectives of fisheries management might be to maintain certain options for its citizens. For example, in parts of the United States a number of part-time employed or retired individuals supplement their incomes by fishing. Other objectives may relate to recreational and esthetic opportunities.

In developed countries where fisheries have been historically a major activity, management goals may be strongly associated with maintenance of the resource. Frequently, the goal of maximum sustainable yield is mentioned. However, excessive fishing capacity (overcapitalization) has required managers to reexamine goals and modes of achieving objectives. Great attention is being given to rules to govern the number of units operating in a fishery and their total extractive power.

In developing countries, management goals may be different. The objectives of fisheries exploitation may be to generate goods and services that contribute to the Gross National Product, to produce a supply of protein foods, and to provide sources of foreign currency. In countries having latent resources adjacent to their coasts, the objectives of management may be to appraise such resources, to determine the profit opportunities in such fisheries, and to compare these with opportunities in other fields. The goals of the national fishery agency might be information on distribution and abundance of resources, cost of harvesting, price demand structure, and estimates of sustainable yields (Marr 1972).

One principal objective of aquatic resource management currently being debated in the Preparatory Conferences on Law of the Sea relates to the "allocation" of resources available. The problem is economic in character and has not for the most part been effectively dealt with in existing national or international institutions that manage fisheries.

It has been suggested that management policies and objectives should be based on analysis of the interest of all user groups of marine resources, and that the principal considerations governing allocation of resources should be those related to preservation, recreation, and commercial utilization. These diverse interests, however, are not easily reconciled at a national level and are even more intractable at the international level. We cannot escape the conclusion that in the 1970s a principal task of aquatic resource management at national and international levels will be to deal with the problem of resource allocation.

The complexities of socioeconomic goals have led managers to state objectives in somewhat broader terms. For example, McKernan (1972a) proposed that "the overriding consideration of a national fisheries objective should be the preservation of the resources at an economic level of productivity for future citizens of our country" – an objective with both conservation and economic implications; secondary objectives could be attainment of national benefits – economic, recreational, and esthetic. Others have suggested similar goals; for example, that the socioeconomic objectives of fisheries should be their regulation to yield maximum benefits from the resources, with due consideration for all national and international requirements. These socioeconomic objectives require a value system to compare intra-socioeconomic objectives with those concerned with the welfare of the resource.

The variability of economic and social objectives at a national level is complicated by even greater disparities in views from country to country, as well as between economically developed and developing regions and countries.

NATIONAL AND INTERNATIONAL POLITICAL OBJECTIVES

Although we most frequently think of aquatic resource management in terms of maintenance of the resources or socioeconomic goals, national and international politics may lead to objectives of a different character.

At an international level, the national political objectives may be to establish a legal order for managing man's activities on the oceans so as to create a more harmonious relationship among the user groups of the ocean resources (Alverson 1973). Hence, certain policies may be formulated to resolve contentious issues. They may be concerned with resolving arguments arising from gear conflicts, or with easing tensions between elements of the international fishing community competing for limited resources — the objective being to maintain a degree of international stability.

National objectives may also reflect a desire to participate in management processes and to further conservational, socioeconomic, or political objectives, even when the nation does not harvest the resource in question. For example, the United States continues to participate in the International Whaling Commission (IWC) although it no longer engages in the exploitation of whales. In a similar vein, governments may wish to maintain management and exploitation options or improve their technical and scientific management abilities through participation in organizations concerned with regulation.

Finally, national security may be involved in the aquatic management objectives of certain nations. This may be related to acquisition of environmental or resource information considered pertinent to national security, or in developing and managing fisheries as a basis for maintaining and extending international ties and prestige in ocean affairs (Chapman 1968).

Problems in Managing Aquatic Resources

Problems associated with achieving the objectives of effective management of aquatic living resources have been discussed by a number of authors. There appears to be more agreement on the nature of problems than on objectives. Failure to achieve certain conservation and socioeconomic goals derives from a lack of understanding of the dynamic resources to be managed, from frailties in decision-making processes, or from a hazy comprehension of the essential functions of management by those given the mandate.

To understand problems uniquely associated with the management of living ocean resources, it is important to recognize that the principal exploitive industry (the fishing industry) is the only remaining major food-producing system in the world which relies on hunting procedures, exploits wild stocks, and harvests stocks that are for the most part considered the common property of all sovereign nations or their citizens. These facts, which set fisheries apart from other food industries, require successful users to deal with problems generated by the dynamic nature of the stocks and their common property aspects.

A variety of causes for the failures to properly develop and manage fisheries are noted in fisheries literature. They include: unlimited access to common property resources; archaic institutional constraints and legal measures which handicap technical innovation and protect the status quo; fragmentation of jurisdiction at state, federal, and international levels; lethargy and force of tradition among entrepreneurs; lack of vertical economic integration of the industry; overcapitalization, overfishing, lack of scientific information on the exploited resources, inadequate theory, etc. (Marr 1972; Joseph 1972a; Gulland 1972; Wenk 1972; McKernan 1972b).

Elaborating on problems of aquatic resource management, Alverson (1973) suggests several factors which have inhibited effective management of living resources. They include: (1) awkward institutional arrangements for implementing management schemes; (2) failure of scientists and administrators to differentiate the roles of science and management and to recognize underlying economic factors; (3) failure of science to provide information and appropriate models which allow timely management decisions; and (4) adherence to rigorous scientific methodology as a basis for management decisions — particularly a religious dedication to this concept in terms of managing international fisheries. Problems associated with monitoring and enforcing regulations governing the use of living aquatic resources, and environmental degradation created by the aggregate of man's terrestrial and maritime activities might be added.

The problems confronting managers have been grouped under the following subtitles: a changing world, the nature of objectives, management institutions, allocation of resources, adequacy of scientific input, enforcement, and multiple-use conflicts.

A Changing World

Speaking at the Fiftieth Anniversary Celebration of the College of Fisheries of the University of Washington the Deputy Director-General of FAO, Roy Jackson (1972), said: "Fisheries have changed so vastly over the past 50 years that the problems of development and management have changed not only in magnitude, but in character . . . Most species are fished at or beyond their sustainable yield, and the quantity, efficiency, versatility, range and mobility of the fishing gear and vessels have increased so much and so rapidly that research and management techniques can keep pace only with difficulty, if at all."

In a similar vein Gulland (1971) noted: "Modern fisheries are changing and developing so rapidly that the traditional procedures for scientific assessment of the stock and for the implementation of management measures are no longer entirely appropriate."

Holt (1969) presents convincing evidence of urgency in the need for effective stock management: "The first major conference to examine the state of marine fish stocks on a global basis was the United Nations Scientific Conference on the Conservation and Utilization of Resources, held in 1949 at Lake Success, New York. The small group of fishery scientists gathered there concluded that the only overfished stock at that time were those of a few high-priced species in the North Atlantic and North Pacific, in particular plaice, halibut, and salmon. They produced a map showing 30 other known major stocks they believed to be underfished. The situation was re-examined in 1968. Fishing on half of those 30 stocks is now close to or beyond that required for maximum yield. The fully fished or overexploited stocks include some tunas in most ocean areas, the herring, the cod, and the ocean perch in the North Atlantic, and the anchovy in the southeastern Pacific. The point is that history of development of a fishery from small beginnings to the stage of full utilization or overutilization can, in the modern world, be compressed into a very few years."

Fisheries have grown at a rate of 6.6%/year during the last decade, and the number of fully exploited species has also increased rapidly so that finding underutilized conventional forms is becoming more difficult. The problem is aggravated by world demand for fisheries production, which is increasing more rapidly than the supply, thus accelerating competition for the raw material and at the same time making the analysis of status of stocks more complex.

Although technological development is at a high level and continues to accelerate, many of the serious problems have not been ameliorated by this development, and in some instances have become more severe (Rothschild 1971). Churchman (1968) concluded that the technological capacity to solve these problems exists, but solutions have not usually been forthcoming. The paradox seems to lie in the fact that our problems are not as simple as they were, and existing attempts to resolve problems on a piecemeal basis or in a leisurely fashion are no longer adequate (Rothschild 1971).

In a world that has changed so rapidly since the last FAO conference on world fish stocks, relative rates of change are exceedingly important. Although our ability to manage fish stocks has grown rapidly during this period, our ability to harvest has increased even more dramatically and the gap between managerial ability and exploitative technology has widened.

Nature of Objectives

McKernan (1972a) noted that some problems associated with aquatic resource management can be associated with ". . . conflicting political, economic and conservation objectives of management, some local, some regional, and some international, and these conflicting objectives have led to a great variety of results, most of them bad."

It is undoubtedly true that the array of objectives proposed by policy makers, scientists, administrators, etc., are frequently not reconcilable one with the other; and in some instances narrowly defined objectives have created more problems than they have solved. This may indicate that scientists and administrators frequently have hazy concepts of conservation objectives. More often than not, they do not agree among themselves on appropriate goals, and if they do they seldom agree in a functional sense on how they can be attained.

Crutchfield and Zellner (1963) in a study of Pacific halibut fisheries pointed out: ". . . the desirability of controlling a fishery is only a starting point . . . There remains equally the vexing problems of agreeing on the objectives of management and the implementation and enforcement of a workable program."

In a later paper, Crutchfield (1967) emphasized the fact that confusion surrounding the potential and limitation of international management has led to an astonishing lack of agreement on objectives. Frequently the experts to whom the lay community looks for guidance disagree with one another. He noted three positions promoted by the scientific community: "One group steadfastly maintains that the urgency of the world food situation makes a concept of maximum sustained physical yield the only socially acceptable objective. A second argues that the concept of maximum sustained physical yield is both ambiguous and nonoperational under rather common sets of circumstances; they would prefer the term "optimal yield" with a recognized but unspecified social and economic content. A variant of this position holds that while economic objectives are significant in international fisheries management, the inability to define a single optimum acceptable to nations with different economic structures, tastes, and relative factor costs makes it impossible to reach general agreement on any concept of optimal fishing broader than a maximizing of the longrun physical yield."

For several decades maximum sustainable yield (MSY) had been considered a relevant and noncontroversial objective of conservation (Ciriacy-Wantrup 1971). Recently, however, a great number of fishery scientists and administrators have considered this objective as too limited (Crutchfield 1965, 1967; Gulland 1971; Wilimovsky and Alverson 1971; McKernan 1972a; etc.). Others have questioned whether rigid adherence to the MSY concept has produced positive actions required to achieve conservation or socioeconomic goals (Crutchfield 1967; Alverson and Pereyra 1969; Rothschild 1971; Gulland 1972; Fukuda 1973).

Economic objectives are even more hotly debated than are conservation objectives, partly because some proponents seem to feel that one unique objective or set of objectives, if attained, will satisfy all national and international needs. But methods used by conservationists to achieve their goals frequently contribute to the socioeconomic dilemma of user groups instead of resolving it (FAO 1962). As noted by Larkin and Wilimovsky (1973), when management is designed to maintain a status quo for a single species, it frequently encourages sociopolitical constraints which result in technological paralysis and economic inefficiency. Management may then take the form of legislation against better gear, rather than limitation of the number of fishermen or size of catch.

Regulatory actions which discourage efficiency are not necessarily a product of conflicting goals, but stem from a failure to understand fully the interaction of various regulations on other objectives for which a management agency may not be responsible. This suggests that the managers, fishery scientists, social scientists, political scientists, those who would develop and those who would preserve, have not evolved a compatible value system to weigh objectives concerned with management of aquatic resources.

MANAGEMENT INSTITUTIONS

Management of aquatic resources has been traditionally carried out by nationally constituted agencies or by international commissions. Occasionally, however, their management may be achieved through bilateral or multilateral discussions among nations having contentious issues or may be "legislated" at national or international levels. The national institutions responsible for management usually have affiliated scientific bodies to provide information on the status of exploited stocks and an organization to monitor and enforce promulgated regulations. At the international level, scientific advice may be provided by an organization attached to a commission or by scientific agencies (national) associated with the parties to the treaty.

Many problems confronting effective management can be traced to the limited authority invested in management institutions and to the procedures utilized in making management decisions. Authority may be limited in a geographic sense, i.e. the resource under consideration may be partly under national jurisdiction and partly in international waters. The problem of fragmented management has operated to the detriment of fisheries goals, both at national and international levels. In addition, management agencies are frequently restricted to actions concerned solely with conservation objectives. Hence they have not been able to deal — other than in a de facto manner — with socioeconomic problems.

The inevitable climax of many mature fisheries has been the development of more fishing capacity than is required to yield the surplus provided by nature.

Excessive fishing capacity or overcapitalization generates political pressures on the managing agencies to soften the regulation in terms of seasons or quotas, or to encourage regulations which eliminate or restrict the more efficient units in favor of more numerous, less efficient units. Unfortunately directors of government management agencies and individuals selected to serve as commissioners on international bodies are frequently appointees who may be overly sensitive to political pressures. At the international level, the impact of "self interest" politics may be aggravated by organizational arrangements which allow regulations to be imposed only when there is a consensus of the parties concerned. The consequence of responding to these pressures has been a failure to take timely action in terms of conserving the resources.

Timely responses to international management problems, however, may also be inhibited by agreements which demand scientific precision beyond the capability of existing data collecting and processing systems, or by a failure of managers to differentiate between the responsibilities of science and management. Gulland (1971) states ". . . Management has to resolve a wide range of often conflicting objectives of political, social, or economic nature. Science has to provide evidence of the likely results within its field of competence of possible management actions, and so enable more rational decisions to be made. However, since scientific evidence appears to be rather more objective than social or economic considerations, it has been used to make decisions rather than provide one element of the decision making process."

Failures in national and international management have not necessarily resulted from a lack of information concerning changes in the status of a resource. Lack of action may frequently be traced to the assumption that a decision can be made only on the basis of complete understanding — itself an irrational philosophy. An increased data base can, of course, help if information on stock trends allows timely management decisions to be implemented.

Much fault, however, lies with governments which ignore overall management responsibilities, or are unable to implement them. As a consequence, many resource management agencies are losing credibility. The fact that an international or governmental organization is managing a resource and has a staff of "experts" is no longer sufficient to ensure a course of action (Wilimovsky and Alverson 1971).

When international contentious issues cannot be resolved through bilateral or multilateral negotiation, there is, theoretically, recourse through international agreements and arrangements provided by the 1958-1960 Geneva Convention. The difficulties in utilizing existing legal arrangements provided by this Convention, however, were expressed by Ambassador Jorge Castañeda (1971) of Mexico in the July–August 1971 Preparatory Conference on Law of the Sea. The Ambassador stated that the rights provided by the existing Convention were almost useless: "Do you want proof that this is so? In the 13 years that have transpired since the Convention was consummated, this new and important right (coastal state preference and unilateral implementation of conservation) has not once been exercised in any part of the world. There exists, however, a great number of cases in which the coastal state has been obligated to tolerate excessive abuse by foreigners along its coast . . ."

Finally, there are legislative actions taken to manage aquatic resources that arise at both national and international levels in response to public opinion. Management by legislative bodies frequently is not based on scientific advice, but is a reaction to internal political pressures and emotionally stimulated rhetoric. Such legislation is likely to be based on false premises. However, at times it is generated by a failure of constituted management agencies to take action in a timely fashion, or by the absence of an appropriate management organization.

Allocation of Resources

If one had to classify the basis for regulations governing the uses of marine living resources, both coastal and oceanic, the status of the stock would be the rationale most frequently given for a management action. However, allocation of the resources and economic status of the user are obviously involved. Although the key word is international management is also "conservation", more frequently the contentious issue involves allocation of a resource among multiple user groups (Alverson 1973).

The problem is an outgrowth of the common property aspect of aquatic resources, and its importance has increased exponentially as the world community has come into increased competition for available ocean protein.

Although almost all national interventions given at the recent Preparatory Conferences on Law of the Sea dealing with fisheries matters stress the problem of conservation, the additional theme of allocation is obvious. The emergence of the terms "preferential right" or "right of the coastal state" over certain living resources often stems from socioeconomic issues rather than from demonstrated conservation problems.

The allocation problem, of course, is not unique to international fisheries management and is a difficult issue that managers must consider at national and regional levels. Managers frequently must make decisions on the allocation of a resource between sport and commercial groups, between different fishing systems (mobile and fixed gear), and must also consider setting aside an aquatic area or a resource so as to maintain fauna assemblages or populations of certain species in their natural state for esthetic reasons. With resources becoming more scarce, there is also the problem of allocating the surplus produced by a fish stock between those who would harvest it to provide food for direct human consumption and those who would use it to produce industrial products.

Adequacy of Scientific Input

The theoretical basis for what now constitutes the science of fisheries population dynamics was established between the 1920s and the mid-1950s. The early works of Baranov (1918) and Russell (1931) were translated into workable and quantitative procedures by such scientists as Thompson and Bell (1934); Graham (1935); Beverton and Holt (1957); Scharfer (1954a, 1954b); and Ricker (1954, 1958), and three conceptual approaches emerge from their investigations. These are known as: (1) the stock-production or sigmoid curve theory; (2) the production-per-unit-recruitment or dynamic pool model; and (3) the stock-recruitment or parent-progeny approach. These three theoretical approaches have been widely applied during the past 15 years.

Stock production models assume that the surpluses produced are a function of stock size and that the maximum excess occurs at about one-half the maximum stock size (logistic curve) that can be carried by a given environment. For other types of relationships maximum surplus may occur at different stock sizes (Pella and Tomlinson 1969). Data inputs into the models generally require only catch and effort statistics and do not demand that the age of the fish be determined. Similarly, they do not require information on growth or natural mortality rates or other life history parameters. The major advantage of models of this character is that (owing to their limited data requirements) they tend to be easily understood (Rothschild 1971).

Production models, however, have several limitations and operate on assumptions that are difficult to fulfill. They provide only general guidance as to management strategy under average conditions; they assume an instantaneous response to changes in stock abundance; and they imply that environmental conditions are stable and do not greatly affect stock productivity. In addition, these models assume that qualitative characteristics of the stock, such as age and size distribution, do not affect its productivity, i.e. the stock can be treated as a single biological unit.

One fragile assumption of the production model is that catch-per-unit-effort (CPUE), the index used to measure abundance, is proportional to population density at all levels of stock size. There is increasing evidence, particularly in developing fisheries, but perhaps also in mature fisheries, that factors operate to bias relations between normal effort and true fishing mortality over time. The major factors which may bias this relation are: (1) the fishing area may expand with time; (2) the catchability coefficient may change drastically with changes in fishing gear, tactics, etc.; (3) a large year-class passing through a fishery may bias normal catch-effort data; (4) qualitative changes in the stock which may be important are totally ignored by the model; and (5) behavior patterns of individuals comprising the resource may act to alter the coefficient of catchability with time.

The production-per-unit-recruit or dynamic pool model is based on the fact that knowledge of growth and mortality factors permits one to predict the age (critical age or size) at which a cohort or year-class will maximize its weight. The model assumes that yield will increase steadily with increased fishing effort (the eumetric fishing concept) and will asymptotically approach the maximum potential weight of the cohort as instantaneous fishing mortality increases and average size at first exploitation simultaneously approaches "critical size." The yield to be expected from a given number of recruits can be computed under a variety of fishing conditions using various tables (Wilimovsky and Wicklund 1963; Beverton and Holt 1966); and variable assumptions concerning mortality and growth can be easily incorporated into the yield-per-recruit model with the aid of tables and computer routines (Rothschild 1971).

Perhaps the greatest disadvantage of this approach is the reliance on the assumption that within the range and stock sizes at which fisheries can economically afford to operate, a stock recruitment problem is not involved. One may be lulled into accepting an assumption not actually valid. We may well have reached a point in many fisheries where stock sizes can be, or have been, reduced to levels at which stock-recruitment relations take on great importance. At this point, the incorporation of stock-recruitment approaches into management theory is indicated.

The stock recruitment model is perhaps the most difficult to deal with. It assumes that recruitment under similar environmental conditions will be a function of stock size. If the relation between spawning stock and recruitment can be established, then a management philosophy can be developed which maintains the parental stock at a size which produces a predictable recruitment. Establishing stock-recruitment relations is, however, complex; in many cases they have not been defined. Stock-recruitment relations are generally studied by plotting indices of stock size against some index of recruitment. Frequently the result is a scattering of points exhibiting little correlation. More extensive use of the concept will require further development of new stock-recruitment models and evolution of indices which predict recruitment as a function of environment and adult stock size (Cushing 1973).

These various models have been embellished in recent years, yet they have not been replaced or even displaced by new theories of more sweeping predictive power. During the past two decades, many fisheries scientists have been applying data to these models. By any performance standards, achievements in the science of fisheries population dynamics during the past several decades have been truly outstanding. Few other areas of applied ecology, with the possible exception of forest management and pest control for crop management, have developed theoretical models of their resources and then actually employed the models in terms of regulatory policies.

It is ironic that this success has not motivated new efforts to develop more comprehensive models. Reliance on the traditional models has operated to dampen innovative or exploratory thrusts by various fishery commissions, agencies, and regulatory groups. Once a certain model has been adopted by a regulatory agency, there appear strong pressures for the agency to maintain the status quo and little incentive to upgrade the state of art; rather, it becomes a process of merely adding a data point to the basic management graph year after year. At times obvious deficiencies develop in applying certain management models, but the agencies' basic operational techniques (e.g. data banking and sampling schemes) act as strong vested interests to prevent change.

The existing science of fisheries population dynamics has been greatly affected by the manner in which its products are applied. Theories that purport to explain the dynamics of fish stocks must be tested and verified by observations in the real world. The types of observations available, to a great extent, determine the types of hypotheses that can be tested and the nature of theories that will ultimately prevail. Unfortunately the problem of verification has been complicated by the existence of data systems which frequently are not designed for managerial purposes (Wilimovsky and Alverson 1971; Marr 1972), or are restricted in their use because of varying standards used for collecting and reporting fisheries statistics. In many instances, observations on quantities of fish caught by area are made for tax purposes or to assist private enterprise or governments in carrying out their harvesting activity. Only in recent years have information systems been designed to collect data in the manner and detail required for scientific management of the resources. Information systems of this character, however, are even now confined to relatively few fisheries and geographic areas.

The problem is compounded by the cost of collection and analysis of such statistical information and many governments have not been willing (or could not afford) to assume the obligation for detailed documentation of fishing activities.

Many authors have complained that traditional fishery models frequently have little utility in today's modern fisheries (Gulland 1971, 1972; Alverson 1972; McHugh 1972). For the most part, fisheries theory was designed to treat individual stocks as isolated entities, independent of their competitors, predators, and prey, and affected little by environmental fluctuations. The pace of events was much slower when the models were evolved. The rapid rate of growth in fisheries and changes in fisheries strategy, tactics, and technology, fleet mobility, etc., have made it extremely difficult to rely on abundance indices based on fishery catch statistics. In addition, most of the models discussed earlier are based on steady state conditions. This is particularly true for the simpler forms of the Beverton and Holt (1957) and Ricker (1958) models. The Schaefer (1954a) model may be more responsive to the dynamic nature of modern fisheries, but is not strictly applicable when major changes in recruitment occur in a period shorter than a generation.

Gulland (1971) in a discussion of this problem states: "Even when applicable, these methods of analysis are not well suited to providing early warnings of the need for management. They depend (at least in their simpler forms) on detecting fisheries-induced changes in the characteristics of the fish population (catch-per-unit-of-effort, total mortality, etc.) and given the normal variation of fisheries data, these are not easily detected until the population has been substantially affected by fishing and often reduced to a level approaching or even below that which would be most desirable by some criterion."

In this sense, the rate of change of fisheries and reliance on traditional models almost insures that overfishing must occur as an antecedent to a management decision.

Part of the problem may reflect an attitude of some scientists that, given time and adequate funds, complete answers to management problems can be produced. Gulland (1971) in addressing this problem stated: "Scientific finality cannot be achieved. Science advances by disproof rather than proof: a succession of hypotheses are put forward capable of explaining the observed facts, and have to be abandoned or revised as further observations show them to be inadequate. Complete and final scientific advice cannot therefore be provided; all that can, or should, be provided, is advice that is sufficiently accurate and detailed for the immediate purpose."

The traditional models also have limitations as they relate to the development of latent fisheries (Marr 1972; Joseph 1972b; Gulland 1972). The models are of little utility to countries in the process of developing new fisheries. Establishing criteria on which to manage developing fisheries remains a problem — one which the population dynamicists and fishery biologists need to consider by use of both empirical and theoretical approaches. The Food and Agriculture Organization of the United Nations has attempted in recent years to develop fisheries manuals to provide guidance to developing countries on methods of assessing latent resources; several authors have proposed methods to make first approximations of stock sizes and yields (Alverson and Pereyra 1969; Allen 1971; Gulland 1971; and Joseph 1972a, b).

ENFORCEMENT

Perhaps no management problem looms larger to conservationists and fishermen than that of enforcement. Although a variety of regulations governing use of living aquatic resources are promulgated, there is considerable difficulty in monitoring subsequent activities of user groups and insuring that the regulations are being adhered to. This is particularly true on the high seas, where vast distances and areas are concerned and government enforcement craft are few and far between. Although some enforcement is possible at dockside, the application of gear restrictions (cod-end mesh sizes, number of pot units that can be fished, limitation on retention of incidentally caught species, etc.) is extremely difficult to enforce at sea.

International enforcement is a major problem. In many instances, states which are party to treaties do not allow their vessels to be inspected on the high seas by other nations. Coastal fishermen frequently feel that foreign vessels operating off their coast (but beyond the territorial sea) are not operating in a manner consistent with conservation principles. Even when bilateral or multilateral agreements can be made between the concerned parties, more often than not there is no method to monitor and insure that the agreements are being honored. Although this problem may be more "suspect" than substance, in the eyes of many fishermen and the lay public the existing enforcement systems are not working. Further, there can be little doubt that problems of international enforcement over the millions of square miles where fishing vessels operate is a difficult and costly problem.

MULTIPLE-USE CONFLICTS

As noted earlier, fisheries have grown at an extremely fast pace during the past 30 years. The fishing industry has been, until recently, the major economic unit exploiting the oceans' resources. The situation, however, is changing rapidly. Both oil and minerals are being sought on the continental shelf and slope. In addition, estuaries are being used for a variety of industrial and recreational purposes; and aquatic environments are increasingly used to dispose of industrial and human wastes. Multiple-use of the aquatic environment will doubtless continue to increase.

Management agencies cannot assume that pollution problems will be resolved in time to maintain present biological production. Man needs the oceans also for transportation, as a source of minerals, as real estate and industrial sites, and as a sink to dispose of waste products, and all this is likely to degrade their biological production. To minimize duplication of effort and increase communication between groups studying the oceans, effective mechanisms and interactions between responsible agencies and user groups will be needed (Wilimovsky and Alverson 1971).

Discussion

Management of aquatic living resources had its origin early in man's history. The goals proliferated as man began to use a wider range of resources and as his exploitative technology extended the range and scope of his operations. The need for animal protein to feed increasing populations has come into conflict with the desire to use the aquatic environment for industrial purposes, or to preserve certain resources for recreation or for esthetic reasons.

Conservation goals, as they relate to fishing, are concerned with maintenance of stocks at levels which will yield the greatest sustained surplus. Socioeconomic goals are concerned with achieving economic efficiency, allocating the resources between user groups, maintenance of social options, resource development, etc. The goals have been discussed in detail; it is important only to emphasize the increasing complexity of these goals, and the need for more sophisticated mechanisms to attain objectives. Sir Solly Zuckerman, a former scientific advisor to the British Government, stated: "We live in a period of uncontrolled and accelerating change, an age in which technology has raced ahead, and in which hallowed social values have tumbled . . . We live in an age of paradox: an age in which the politician has been straining after the scientist and technologist, and in which the latter have been trying to understand the social consequences of the innovations to which their work has led. The world is clearly living through a period in which the aims of politics and the outcome of scientific endeavor appear to clash." If management of living aquatic resources is to be more successful in future, it must recognize the need to evolve decision-making machinery that is responsive to the rapid changes occurring in fisheries. At the same time, it must recognize that a great variety of national and international management objectives and policies exist. In order to establish some semblance of order and effectiveness, the same objectives and policies must be recognized throughout the management hierarchy; and the world community must establish methods of making value judgements based on principles associated with its objectives.

Rounds (1971) in a paper presented to the United Nations Industrial Development Organization in Santiago, Chile, stated: "Value systems are not only ubiquitous but indispensable in every culture. If management is to deal realistically with the problem of defining requirements for systems involving resolution of multiple, complex problems, such as labor relations, public relations, morale, equipment performance, communications and teamwork, then management must be realistic about the potential conflicts in human values. Despite the fact that many human values are inconsistent, conflicting, and unrealistic and so are dubious guides to beliefs, attitudes, and actions, they are a fact of life and must be considered. It must be recognized that basic values differ widely from individual to individual, group to group, and culture to culture. Moreover, these values are dynamic in nature and are subject to change within cultures and groups and even within individuals over a period of time."

Institutions set up by national and international agencies to deal with management problems must broaden the scope of their objectives or at least clearly recognize the impact of their decisions on other national or international goals.

A clarification of the changing legal concepts as they deal with jurisdiction over resources or sections of the aquatic environment may be required before radically new management concepts can surface. Changes in jurisdictional concepts, however, will not necessarily lead to more efficient management. Jurisdictional changes will provide a new legal substrate on which managers can formulate and implement conservation activities. Change can provide for new and different management opportunities. However, many of the fundamental problems will remain; and their resolution will depend on the powers given the management agency, its depth of understanding of the reaction of resources to natural and human events, and the willingness of governments and managers to assume the responsibilities delegated to them, including the promulgation and enforcement of appropriate regulations.

Managers cannot expect the debates over appropriate goals to narrow and the scientific community to achieve unanimity, or that it is necessary to achieve unanimity concerning the most appropriate management techniques or the status of fish stocks. Managers must recognize that debate is a healthy and necessary role of science. Our advice to managers is that the rhetoric will continue, but we cannot afford to postpone much longer important decisions regarding the management of aquatic living resources and of the environment.

Sir Solly Zuckerman summed up the situation rather adroitly: "Since the scientist is in the public arena only as the expert worker and adviser, it is his employer, whether it be the government or the board of an industrial company, which commands his service and which has the responsibility for action. The decision whether to accept or reject his advice is theirs and theirs only."

Although the responsibility for action is clearly in the hands of management, the scientific community must play an important role in producing relevant information on which decisions can be based. Fishery scientists who wish to contribute to better management must: more effectively communicate their findings and concepts to managers; develop data acquisition and analysis modes which allow for timely decisions; accelerate understanding of density-dependent processes that control abundance and productivity of aquatic life; develop assessment modes which are independent of fishery production statistics; evolve methods of providing quick diagnoses of the status of individual stocks, mixed stocks, or species aggregates; contribute to the development of theory and application of the total systems approach to management of renewable natural resources; and design and encourage experimental management regimes.[4]

Finally, one should not forget that maintenance of the aquatic living resources at productive levels is a prerequisite to achieving almost all socioeconomic goals. It does not necessarily follow, however, that the objective of the population dynamicist is to focus on the maximum sustainable yield of a species or species complex. It is more useful to provide a broad range of information on the anticipated responses of the resource and the expected yields (or range of yields) that would result from alternative fishing strategies. This would provide managers with greater flexibility in the interpretation and consideration of options available to achieve both conservation and socioeconomic objectives.

Dedication

This paper is dedicated to Dr Gerald J. Paulik (1931–72). The Food and Agriculture Organization of the United Nations (FAO) originally requested Dr Paulik to prepare the review paper on the objectives and problems of managing aquatic living resources. Dr Paulik died on October 7, 1972. Shortly before his death, he requested that I assist him in the preparation of the paper. His notes were reviewed extensively and an attempt was made to incorporate many of his views into this document. I must, however, assume full responsibility for style, content, and the views expressed.—D. L. ALVERSON

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Contemporary Methods and Future Trends in Fishery Management and Development[1]

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Fisheries management is best viewed as it departs from what might be called "nonmanagement" – when there are no interventions. Left unmanaged, fisheries develop to successive periods of stability that are ultimately characterized by relatively fixed techniques of harvest and a fixed total catch. The catch changes from a few preferred species to any acceptable species, and stabilizes on a few species most capable of withstanding the harvesting. Even in the simplest case of single jurisdiction fisheries for a single species efforts are largely tentative and feeble. Where management achieves the objective of regulating total catch, it is commonly accompanied by technological paralysis and economic inefficiency, unless entry into the fishery is limited. Multinational coastal fisheries add the element of reconciliation of differing social and economic goals, and over-riding considerations of national interest. The question of what constitutes a suitable management zone is troublesome and there is no simple rule of any biological significance. Pelagic fishes are particularly vulnerable to overexploitation from multinational fisheries. Anadromous species have the added element of investment in preservation of the obligatory freshwater environment. Fisheries management will increasingly be considered in the more general contexts of management of marine resources and the impacts of land use on the world's oceans. Aquaculture gives promise of potential for fish production in strategic places. The logic of these operations seems indisputable in the long run, and they should increasingly contribute to world fish production.

In broad perspective it seems likely that levels of exploitation of existing fisheries are approaching those that are maximally sustainable. There is urgency in the need to intervene successfully in the largely unmanaged fisheries of the world. The present set of devices to accomplish these ends is essentially a patchwork of agreements supported by only the most general principles of international agreement. For the future the paths are: to let the fisheries run an unmanaged course to eventual stabilization, posing risks of creating situations that may not readily be rehabilitated; to consider radical new kinds of international agreements; or to develop the present pattern of agreements more vigorously. The prospect seems to be for only limited success on the third path, with a difficult transition to more stabilized world fisheries partly a product of management and partly of nonmanagement. The development of new technologies and social attitudes could lead to different prospects for the use of the world's living ocean resources.

Pour comprendre ce qu'est l'aménagement des pêches le mieux est de considérer ce qu'elles sont en l'absence de toute intervention. Laissées à leurs propres moyens, les pêcheries passent par des périodes successives de stabilité, la stabilisation ultime étant caractérisée par des techniques d'exploitation relativement fixes et une prise totale inchangée. Les captures de quelques espèces préférées sont remplacées par celles de n'importe quel poisson acceptable pour le consommateur et se stabilisent finalement sur un certain nombre d'espèces les plus aptes à résister aux effets de l'exploitation. Même dans le cas le plus simple de pêcheries dépendant d'une juridiction unique réglementant une seule espèce, les interventions sont, pour une large part, expérimentales et faibles. Lorsque l'aménagement réussit à réglementer les prises totales, il est généralement accompagné d'une paralysie technologique et d'une mauvaise rentabilité, à moins que l'accès à la pêcherie ne soit limité. Les pêcheries côtières multinationales aident à concilier des objectifs sociaux et économiques divergents et des considérations primordiales d'intérêt national. La question de savoir ce qu'est une zone propre à l'aménagement est embarrassante et du point de vue biologique il n'existe pas de règle simple. Les poissons pélagiques sont particulièrement vulnérables à la surexploitation par des pêches multinationales. Pour les espèces anadromes, il faut en outre considérer les investissements nécessaires à la préservation des eaux douces. L'aménagement des pêches sera de plus en plus envisagé dans le contexte général de l'exploitation des ressources marines, en tenant compte des répercussions qu'à l'utilisation des terres sur les océans. L'aquiculture offre des possibilités de production halieutique à des endroits stratégiques. La logique de ces

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opérations semble incontestable à longue échéance; elles devraient contribuer toujours davantage à la production mondiale de poisson.

Dans une large perspective, il semble probable que les niveaux actuels d'exploitation des pêcheries se rapprochent du taux maximum d'extraction. Il est urgent d'intervenir avec succès dans les pêches qui restent pour une large part non aménagées. Les dispositifs conçus à cet effet représentent un ensemble d'arrangements disparates qui ne s'appuient que sur les principes les plus généraux d'un accord international. Pour l'avenir, les solutions pourraient être les suivantes: laisser les pêcheries opérer sans intervention jusqu'à la stabilisation finale, ce qui entraînerait le risque de créer des situations peut-être difficiles à redresser; envisager de nouvelles formes, plus strictes, d'accords internationaux; ou renforcer le régime d'accords actuellement en vigueur. Cette dernière solution ne semble promettre qu'un succès limité, avec une transition difficile vers des pêcheries mondiales plus stabilisées qui seraient en partie aménagées et en partie non aménagées. La mise au point de nouvelles techniques et un changement dans les attitudes sociales pourraient modifier les perspectives quant à l'utilisation des ressources biologiques que recèlent les mers du globe.

La reglamentación de la pesca se comprende mejor si se la compara con lo que podría denominarse "no reglamentación," es decir, con la ausencia de intervención. Dejadas a sí mismas, las pesquerías atraviesan períodos sucesivos de estabilidad, el último de los cuales se caracteriza por el empleo de técnicas de explotación relativamente fijas y una captura total también fija. La captura se amplía, y de algunas especies preferidas pasa a abarcar toda especie aceptable; por último se estabiliza en torno a algunas especies que son más capaces de resistir los efectos de la explotación. Incluso en el caso más sencillo, es decir cuando se trata de una pesquería de una única especie y sometida a una única jurisdicción, estos esfuerzos son en buena parte experimentales y débiles. Cuando la regulación consigue el objetivo de regular la captura total, le sigue de ordinario una parálisis tecnológica y una ineficiencia económica, a menos que se limite el acceso a la pesquería. En las pesquerías costeras multinacionales se añade además el problema de poner de acuerdo los diversos intereses sociales y económicos y las consideraciones prevalentes de interés nacional. La cuestión de qué se entiende por una zona adecuada de regulación es compleja y no existe ninguna norma sencilla que tenga valor biológico. Las especies pelágicas son especialmente vulnerables a una explotación excesiva en pesquerías multinacionales. En las especies anadromas hay que tener en cuenta además las inversiones necesarias para la conservación del medio ambiente de aguas dulces. La regulación del sector pesquero habrá de entenderse cada vez más dentro del concepto más general de la regulación de los recursos marinos y de las repercusiones del empleo de la tierra en los océanos. La acuicultura ofrece buenas perspectivas de producción de pescado en zonas estratégicas. La lógica de estas operaciones parece indiscutible a largo plazo y ellas contribuirán cada vez más a la producción mundial de pescado.

En general, es probable que el grado actual de explotación de las pesquerías esté próximo al rendimiento máximo sostenible. Es urgentemente necesario intervenir eficazmente en las pesquerías del mundo, en la mayoría de las cuales no existe una regulación. La serie de instrumentos de que se dispone actualmente para lograr estos objetivos se asemeja esencialmente a una colcha hecha de retales, que en este caso serían los convenios, vinculados sólo por algunos de los principios más generales de todo acuerdo internacional. Para el futuro, las posibilidades son: dejar que las pesquerías sigan su curso, sin regularlas, hasta que lleguen por fin a estabilizarse, con el peligro de que se creen situaciones que tal vez no sea fácil remediar; examinar posibles tipos, radicalmente nuevos, de acuerdos internacionales; o revelar adelante el sistema actual de acuerdos con mayor vigor. Con la tercera posibilidad, las perspectivas de éxito son sólo limitadas, con una difícil transición a pesquerías mundiales más estabilizadas, que serían un producto en parte de la regulación y en parte la ausencia de regulación. La aparición de nuevas tecnologías y actitudes sociales podría abrir diversas perspectivas de empleo de los recursos vivos de los océanos.

Stylized Course of an Unmanaged Fishery

Contemporary practices of fisheries management are best described as they depart from what might be called "nonmanagement." Where there are no interventions, the stylized course of a fishery may be outlined as follows.

First, there is a brief period of exploration, as fishermen investigate the possibility of a remunerative fishery, using existing vessels and gear. If these probes are successful, there follows a period of development, in which experience is enlarged, the number of vessels increased, and competence improved. This process continues until the operation becomes uneconomical for some vessels, whereupon the fishery enters a period of approximate stabilization. Natural fluctuations in abundance of fish are large and there is a likelihood of stabilization at the higher, rather than lower, level of abundance. Then only the more efficient fisherman can sustain good catches. Where there is social mobility those who are less efficient may go elsewhere, but where there is not mobility the less efficient may persist only at a level of chronic poverty.

Introduction of a new type of gear or technique, or a vessel of wider range, may renew expansion of the fishery, giving new vigor until it reaches the next plateau of stabilization. Use of new technologies eliminates many fishermen, bringing about commensurate social stress. The momentum of economic investment may delay the inevitable adjustment and prolong the time required to achieve a new stability. But, in the process of continued free competition, there is gradual selection of the most efficient fishermen and types of gear. Collaboration between fishermen may mean that as a group they fare better than as individuals. Similarly, fishing companies may compete freely or merge or diversify, using the various stratagems of corporate survival. Ultimately, a fully mature fishery emerges with a relatively fixed modus operandi and a relatively stable total catch.

This evolution, of course, has its effects on the prey. In the initial stages, a fishery will usually be centered on relatively abundant, ecologically dominant species. Characteristically, these support substantial rates of harvest, and may even be sufficiently resilient to regain high levels of abundance after being depressed to low levels for long periods. As species, therefore, they are in little danger of extinction; but in the development of a fishery some may be depressed to levels that do not produce the greatest sustained annual harvest.

Much of the effect of a fishery on a single species depends on the range of the fishermen in relation to the range and rates of dispersal of the fish. A highly localized fishery, based on a widely distributed and highly dispersable stock, has no long-term effects on stock abundance, but a wide-ranging fishery may greatly reduce many local stocks. The impact of fishing is thus a consequence of the interaction of the spatial distributions and mobilities of the fish and the fishermen. For these reasons it is characteristic of the early stages of development of a fishery that there is an almost linear relation between effort and catch. As catches decline near the fishing ports, the fleet fishes further away, trading off travelling time against greater catches from unharvested segments of the stock.

As the yield of preferred species declines, the fishermen may turn in part to other species that are taken jointly and are acceptable to consumers. It is a characteristic of fisheries for almost any species that the current estimate of a maximum sustained yield will be exceeded; but in fisheries for most areas the total yield will gradually increase. This is accomplished by progressive harvesting of more species. The harvest increasingly constitutes a less selective removal, with less emphasis on taking particular species at particular sizes. The rate at which this process develops largely depends on the demand for fish and the broadness of the tastes of the consumers. Ultimately, at least in theory, the rate of harvest is dictated by economics. As the advanced stages of harvesting are approached, theory suggests that fluctuations in abundance of a particular species become more and more extreme as a prelude to their elimination. Sudden rearrangements of relative abundance are to be expected. At present we have only a weak perception of the effects of heavy harvesting on the structure and stability of aquatic communities.

There are two major qualifications to be attached to the foregoing as a summary of how unmanaged fisheries affect the species harvested. Firstly, our understanding is made difficult because the impact on stocks of fish is usually obscured in some degree by natural changes in the physical environment. For example, a fishery may be initiated when it is noticed that there is an abundance of a particular species, but such abundance may be a consequence of unusual and short-lived oceanographic conditions. Similarly, a fishery of long standing may collapse in a few years as a result of oceanographic changes. At all stages in the development of a fishery, fluctuations in environmental conditions may augment or offset the impact of harvesting on abundance. When a fishery is intense and suffers environmental change, it is to be expected that there will be wide, and sometimes almost irreversible, changes in the aquatic community structure.

Secondly, it is pertinent to underline that most of our appreciation of the impact of fisheries is based on experience in the north temperate zone, where there are strong seasonal elements and relatively small numbers of abundant species. Tropical environments are considerably less well known, and their fisheries may be characterized by relatively large numbers of species, none superabundant. In these circumstances, our temperate zone concepts should perhaps be superseded by an approach that treats organisms by communities and trophic levels rather than by species.

The whole process of interaction between a fishery and a group of harvested species may be visualized as a system that evolves with mutual responses, always with a background of environmental variability that influences the biological side of the system, and a context of social and economic factors that influence the human side. The general properties of such systems are not well known, but they seem to trend in the direction of greatest productive efficiency if left to their own devices.

Management of Fisheries

The interaction between a fishery and an aquatic community may be subject to a variety of human interventions, which may be called "management" in the broadest sense of the word. Bearing in mind the range of these interventions, and the variety of habits of fish, one may distinguish five kinds of situations: Single jurisdiction fisheries in inland waters or for coastal species confined to waters within X miles of shore; Multinational fisheries for coastal species that range generally over the continental shelf, further than the species assignable to the first situation. Also included are multinational fisheries in inland waters; Fisheries for pelagic species that usually occur only beyond Y miles from the coast and can be clearly considered as inhabiting "international" waters; Fisheries for anadromous species that migrate from fresh to offshore waters, as exemplified by salmon; Aquaculture potentials.

Each of these categories poses its own problems for effectiveness of intervention, involving different patterns of management and posing different problems for the future.

SINGLE JURISDICTION FISHERIES IN INLAND WATERS OR FOR COASTAL SPECIES

Inland and near-coastal fisheries are usually within a single governmental jurisdiction, the interventions taking place in the context of a single set of economic and social considerations. It may be decided at any stage to try to maintain a status quo, to accelerate some transition, or to let "nonmanagement" take its natural course. For example, it may be decided that the total catch of a particular species should not exceed a maximum sustainable yield, constrained by mesh size or effort. This may be considered desirable because of the high value of the species concerned, and the likelihood that its ecological or economical replacement (if any) will not provide an equal return.

The biologically necessary tactics of intervention are usually: regulations making it illegal to take fish below a certain size—by rules concerning mesh size, by closure of "nursery" areas, and so on; specification of the total permissible catch, with annual or seasonal adjustments related to the fluctuations in stock abundance; provision for protection of spawning fish where they are particularly vulnerable, and where recruitment may be the predominant consideration for maximum sustained yield.

The technique used for catching fish almost invariably dictates the pattern of regulation. Fishermen use the most effective methods they know, and where these are incompatible with achievement of yield objectives they may be constrained or prohibited. The effectiveness of regulation often depends heavily on adequacy of statistics and enforcement.

There are few examples in the world of successful management of inland or near-coastal fisheries along these lines, although single jurisdiction fisheries would seem to pose the simplest challenges to management. In many cases the reasons given are that the fisheries do not have an adequate base for management; that there is insufficient knowledge of the species, inadequate documentation of catch and effort, and inadequate staff for enforcement.

While these reasons are no doubt based on fact, to a degree they should be construed as rationalized excuses. Successful management should proceed from decisions taken on inadequate knowledge to decisions made on less inadequate knowledge. In practice it is more common to delay decision until "disaster" approaches, and then to expect hasty action to provide quick solutions. The fishery scientist is in some measure responsible because of reluctance to recommend or predict on "incomplete" data. Fishermen are understandably anxious to catch as much as possible. A government is reluctant to impose what may be unnecessary restrictions. In these circumstances, management is largely tentative and feeble, is not demonstrably successful, and is frequently inconsistent.

For a few valuable near-coastal species, for which there is a single jurisdiction, the necessary scientific and statistical services have been developed and regulations made. From a biological point of view managing single species stocks is only a matter of application of known techniques. There are many examples of failures to manage "correctly," even with adequate information (e.g. British Columbia herring), but in general these are local and temporary setbacks, which can be diagnosed and avoided in future management of the rehabilitated stocks. One of the major technical difficulties is the detection of increases in the fishing effort exerted by a unit of gear, particularly in a period of rapid technological change. This problem may be further compounded when lost gear (e.g. crab pots, shrimp traps) continues to harvest for a long period, or where mortality is otherwise inadvertently caused and is not recorded.

Where management is designed to maintain a status quo for a single species, it commonly results in technological paralysis and economic inefficiency. With a fixed permissible catch and competition to obtain it, fishermen using better gear or techniques are increasingly less able to obtain returns for the investments unless their number is decreased as their catch capacity is increased (i.e. unless there is a program of "limited entry").

Intervention in these circumstances usually takes the initial form of legislation against better gear rather than limitation of the number of fishermen, the social problem of what to do with people who wish to fish taking precedence over the economic problem of inefficiency. Around the world there are some truly remarkable examples of regulations designed with the prime purpose of decreasing fishing efficiency. But eventually economic considerations prevail as an increasing number of fishermen find it more difficult to make a living regardless of innovations and subsidies of various kinds. There may then follow a scheme of license limitation, which attempts to adjust the fishing effort to the catch to ensure the livelihood of fishermen at minimum state expense.

The situation is usually further complicated when fishermen harvest several species with gear that takes a number of species at once, or when they fish with several kinds of gear consecutively. Thus, a fishery may be characterized by seasonal mobility from one highly prized species to another. This case is a special variation of the single species type of fishery and requires that the fishermen be more versatile, and make bigger investments in gear. Because it provides alternatives, it is more socially stable and economically efficient, but ultimately shares the same problems of readjustment if there is no control over the number of fishermen.

Fisheries that take several species simultaneously are best exemplified by trawling. Where coupled with a fish meal and oil operation, trawlers may be quite indiscriminate in their catch. By utilizing what would otherwise be considered as "waste," they are commendable from a puritan viewpoint, but they may have disastrous consequences by harvesting immature fish of commercial species that are more valuable when caught as adults. Economically, simultaneous multiple species fisheries have the same end point as catching fish consecutively but, because of the resilience of the natural system, multiple species fishing tends to provide greater utilization of the total aquatic community.

Multinational Fisheries for Coastal Species and in Certain Inland Waters

The continental shelf of the oceans produces the major proportion of the world's catch, predominantly of species that occur within and beyond the indisputable national zones. This introduces into fisheries management the complication of international competition, with all that it implies about reconciliation of differing social and economic goals, and overriding considerations of national interest.

In the simplest cases the management of only a single ecologically dominant species may be involved, and the competition (for the foreseeable future at least) may only be between two nations. It then becomes a question of establishing agreement, such as for the maintenance of a maximum sustained yield, and a formula for division of catch, with the provision of the necessary scientific and statistical services for management and the extension of such courtesies as port privileges. The scientific investigation and management functions may be delegated to a "commission" representative of both parties. The problem of management is then reduced to the same basis as with a single jurisdiction, with the added, and possibly overriding, difficulty that inevitable problems of advancing technology and an open entry to the fishery may require the reconciliation of two sets of social and economic considerations.

In such situations a key question of contemporary management is "Does management for maximum sustained yield, by a single nation or by an international convention, establish an exclusive right, a right that may oblige other nations to abstain from fishing that stock?" In effect, this question asks if the social and economic conditions of one or more nations should dictate the pace at which the marine resources of a region should be harvested. In essence, it is a qualified version of the argument that historic participation in a fishery earns a future right to share. Although, in many cases, the contracting parties to such agreements are the nations closest to the resources, this is not a necessary condition. The coastal state adjacent to the stocks may make a further claim to a right to participation in a fishery, even though it has not participated previously, on the grounds that a continental shelf is an integral part of a coastal state. And, of course, there is nothing to stop a coastal nation from harvesting within its own undisputed coastal zone. Finally, a nation may make the double claim that it is a coastal state and has participated historically. With evidence of intent to manage for sustained yield, the historic right may be stated as a claim requiring others to abstain.

If only a single species of fish is involved, a successful pro tem negotiation may proceed from the realization that all claims will ultimately be more rewarding where there is agreement on a maximum sustained yield. But with open entry and advancing technology, a nation may desire to increase its proportion of the total catch, while the others concerned may wish to retain their present proportion. The stage is thus set for increasing difficulty of negotiation, and the possibility that some nations may consider it desirable to exceed the maximum sustained yield and drive out the least efficient. Subsequent negotiation would then presumably favor the most durable competitors, one or more of which would probably be the coastal state(s) with geographic advantage and exclusive prerogatives for fishing near shore.

Regardless of whether a fishery is national or multinational, the question of what constitutes a desirable management zone may also be troublesome. From a biological standpoint, the width of a desirable zone obviously depends on the peculiarities of distribution and migration of the particular species of fish to be harvested. Any single answer is likely to be unsatisfactory for some species, and even for a particular species a desirable width may not be the same on different parts of a coast. In the absence of any convenient single figure, it may be useful to consider the edge of the continental shelf as a marker of biological significance to marine organisms, but it should be underlined that for many species the shelf is not a boundary of any meaning.

The obvious trend of events, if these kinds of fisheries are left "unmanaged," is that eventually the only fishermen who will persist will be those who are technologically most developed, and they will be exploiting the residual aquatic community that represents the least common denominator of taste in fish flesh. At our present state of knowledge, it is not possible to guess which species would persist, nor how stable their numbers would be. It seems unlikely that many species would become extinct, but it also seems unlikely that many of the preferred species would be present in large abundance. As in the case of single species fisheries, the coastal state would probably stand a better chance of inheriting the eventual "remains" and would have the best opportunity to be first back in force when the fishery recovered.

Coastal fisheries problems of these kinds have become increasingly intense in the past few decades, particularly because of the greater range of vessels, fleet tactics, and improved fishing technologies. In many instances, particularly in the western hemisphere, nations have been agreeable to the obvious first step in cooperative management – the provision of statistics of the catch, and some measure of scientific investigation – because it implies better understanding for negotiations. As a consequence, we have a growing documentation of the impact of fishing on stocks. Arising from this information, steps have been taken to regulate mesh size, which will maximize yield for a given level of fishing effort for a given species. Where several species are taken simultaneously, the mesh size chosen is a compromise that underharvests some species while overharvesting others. In some instances there have been further recent interventions, with the establishment of a total catch and national quotas for major species. These measures should contribute to maintenance of a biological status quo, while giving each country its own opportunity to decide how best to handle social and economic problems within its national quota, a problem not dissimilar to that with which it is confronted in inland and narrow coastal fisheries. From the broader perspective, it implies reduced competition and less economic efficiency. Thus, unless some form of multinational limited entry is introduced, the prospect is that coastal fisheries will continue to employ more men and ships than are needed for the job.

A number of large lakes (the great lakes of North America, various lakes in Africa, and so on) present, in miniature, the difficulties of management when there is the added dimension of international claims to ownership of resources. In a lesser degree the same problem exists where several coastal "states" are contiguous to a gulf in which each, although part of a federation, has a jurisdiction over fishing. The examples that come to mind as most conspicuous are not notable for the success of collaborative management. In most instances the stocks of fish involved range through the whole body of water, yet there are few, if any, agreements that have achieved even uniform fishing regulations.

The development of international cooperation for fisheries in large lakes would seem to be imperative. Within such narrow geographic confines it is technologically easy to achieve a devastating level of fishing effort. The slowness with which joint activities have been organized for international lakes is discouraging.

Fisheries for Pelagic Species

In the surface waters beyond, and in some measure over, the continental shelf, the pelagic fish pose a third type of problem in management. The fish occur largely in waters that have traditionally been considered as international, and they commonly traverse wide oceanic distances, often forming only vaguely defined stocks. In a broad ecological sense the pelagic community of fishes is similar to the broad areas of grazing land on many of the world's continental land masses. The interrelations between species are relatively simple and the scale of migrations is large.

For several reasons this may have somewhat different biological consequences than wide-open demersal fisheries in coastal areas. First, the gear employed does not usually harvest indiscriminately. Though there may be some inadvertent capture of undesired species, it is trivial compared to bottom trawling, which may make a substantial "incidental" catch even when the operation is designed to avoid doing so. Second, pelagic fish may have high reproductive rates as a natural adaptation to the vicissitudes of their environment, and may thus be capable in the short term of sustaining high yields. Third, pelagic fish usually school in highly visible ways and may thus be particularly vulnerable to high levels of fishing effort combined with good technology. Because of these characteristics, some pelagic fisheries are potentially highly productive but also highly sensitive to overharvesting. The successes and failures of the catch of herring-like fish are an excellent example. The larger pelagic fish, by virtue of their flexibility as predators and longer life spans, are more resilient to high rates of fishing, but even their wide dispersal is inadequate protection from intensive fishing with modern gear.

Contemporary management of the smaller pelagic species seems to be largely a pattern of overharvesting, often at times of natural environmental changes adverse for spawning. The result has been the collapse of fisheries, sometimes with what seems to be a degree of permanence, either because the residual fishing is sufficient to keep stocks depressed or because other species have moved in. Sufficient experience has now been accumulated to provide a sound biological base for management of herring-like fish but, in general, it has not been applied soon enough to effect the necessary limitation of the fishing effort. Advances in fishing technology have not been appreciated quickly enough and schemes for restriction of the number of vessels have not been implemented soon enough.

Experience with larger pelagic fish has not been as dramatic, but the trend to increased fishing efficiency is progressively requiring shorter seasons to sustain maximum yield. But as the fleets can turn to other species and to new areas, they have an almost global mobility and are increasingly posing the possibility of overharvesting. There is a need therefore for wide-scale agreement on the total fishing effort if yields are to be sustained.

The most extreme example of the effects of advances in technology, unrestricted entry, and vulnerability of the prey because of visibility, is found in the history of the whale. The whale fishery has gone through the various species, has exceeded the maximum sustained yields of most, and has now depressed the total whale community to a low level. Some species may become extinct. Many nations have dropped out of the fishery because it is no longer economical. The whole history of the whaling fishery has been documented by the International Whaling Commission and it provides a good example of overharvesting of a group of pelagic species.

Pelagic fisheries are valuable and vulnerable, and their management, nationally or internationally, has not yet been characterized by effective intervention.

Fisheries for Anadromous Species

Anadromous fish seem to have been created with the special purpose of illustrating the potential problems encountered in fisheries management, ranging from freshwater to high-sea areas, requiring national and international interventions, and being highly vulnerable to exploitation. The Pacific salmon may be taken as a prime example. In the simplest situation, with a single jurisdiction, they are the object of an intense and sophisticated management that is primarily directed at achieving maximum sustained yield for each substock. They are considered sufficiently valuable to warrant rigorous efforts (a century of hatcheries) to increase and rehabilitate stocks, and to introduce them where they do not naturally occur, with equally rigorous efforts to maintain and enhance their freshwater environment in the face of competitive uses. Intervention thus takes the form not only of monitoring production of the fishery, but also of investing in it by positive efforts at the expense of other opportunities.

The chief tools of management are closure of the fishery in various areas at all times (e.g. spawning areas where the fish are extremely vulnerable), and closure of the fishery on some days of each week in each of a large number of small management areas. These practices usually achieve at least a crude adjustment of harvesting rate to the abundance of each stock and, while not altogether successful, have certainly prevented a major decline of most stocks and have been responsible for recovery of others.

Within the rather loosely managed constraint of maximum sustained yield, the salmon fishery has also been regulated in response to various social pressures. The traditional fishing methods have been traps, gillnets, seines, and hook-and-line. At various times and places traps have been banned, the types and amounts of nets limited, and motor boats prohibited. To achieve politically acceptable distribution, there has been juggling of the times and places in which the various kinds of fishing are permitted.

Some technological advances have occurred in vessel design, fleet communication, and the logistics of collection and processing, but from time to time these have been the subject of debate and mooted regulation. Until recently there has been no limitation of the numbers of fishermen of any kind. The number of days fishing has perforce been decreased, in some cases to 2 days out of 7, with a ritualistic beginning on Sunday at 1800 hours the common pattern.

The consequence of this pattern has been to render the fishery increasingly inefficient and mysterious to a detached observer, because of the complexity of the compromises between biological and social objectives, and between various social objectives. The pattern has recently been further complicated by a plan of license limitation, which is aimed at increasing economic efficiency by reducing the number of fishermen faster than fishing effectiveness is increased.

Pacific salmon also provide some stylized examples of the consequences of interventions that have their origin in international considerations. Where Canada is adjacent to the United States mainland and Alaska, salmon bound for each country are intercepted, at least in part fortuitously, by fishermen of the other. Negotiation is essentially based on national interest and is therefore theoretically most expeditious when the interceptions by the two parts are equal. The way is then open for a quid pro quo type of settlement, which is now emerging, and which reflects the principle that the country making the investment in management of stocks should have the benefit. In the absence of equality of interceptions, other political considerations may influence settlement. For example, it may be argued that there is an historic right to continue to take fish, even though they "belong" to another country.

Regardless of the philosophy underlying the settlement, management devices must be invented to accomplish the purposes of an agreement. In the case of sockeye and pink salmon in the Strait of Juan de Fuca and the Gulf of Georgia, the choice to date has been to establish an international commission to arrange the division of catch and conservation (rehabilitation and maximum sustained yield). The commission has its own scientific staff.

Pacific salmon also illustrate another type of international convention in the arrangements by Japan, the USA, and Canada. This treaty is based on the abstention principle, arguing that where a nation, or a group of nations, is undertaking the necessary investigations and management to achieve some maximum sustained yield, other nations must abstain from fishing. Insofar as salmon are concerned, the major intent in this case was to prevent the potentially disastrous effects of high-seas fisheries – harvesting that does not discriminate between salmon of various rivers of origin and, hence, does not adjust catch to stock size on a river-by-river basis (and, incidentally, such a fishery probably does not maximize yield per recruit). However, scientific evidence being what it usually is, there is virtually no conclusive way of demonstrating that management toward maximum yield of the Pacific salmon is indeed being accomplished. Additionally, from time to time there may be "surpluses" which could be harvested to advantage by other nationals.

Fisheries and the More General Contexts of Resource Management

The increasing intensity of use of all world resources has accelerated development of concepts of multiple-purpose use of aquatic resources. There are evidently many possible ways in which the oceans can be used to man's advantage, and increasingly there is evidence of conflict. For example, offshore oil wells pose potential pollution problems; development of superports may influence nearshore fish resources and may impair recreational pursuits; and commercial fishermen and sport fishermen may compete for the same stocks of fish. The extensive use of the oceans as avenues of transport entrains a multitude of effects on fisheries resources. There are many other possible conflicts for the future. Mining of the seabed for nodules could have many effects on organisms inhabiting the ocean floor. It has also been suggested from time to time that fresh water might be obtained in large quantities from sea water and, again, there could be local impacts on fisheries. Various schemes have been suggested for harnessing of tidal power to generate electricity, and these imply a change in natural tidal rhythms. Finally, there have been suggestions that large semienclosed areas of the sea might be modified by the construction of large dams at strategic positions. For example, if the Strait of Belle Isle were blocked, the whole climate of the Gulf of St. Lawrence might be modified, with impact on the whole natural complex of marine organisms.

The development of marine resources near the world's coastlines is thus moving into the stage that, several decades ago, generated multiple-purpose use concepts for land. Accordingly, one would expect to see the development of a similar set of concepts for marine resources. For example, the various proposed uses should each be subject to cost–benefit analysis. Assessments of "optimum use" should be based on comprehensive examination of various alternatives. While it is easy to pay lip service to these sorts of ideals, in practice it may be difficult to develop comprehensive resource use programs. Many of the potential uses are not readily represented adequately in cost–benefit studies. More modern approaches suggest the desirability of constructing computer simulation models that project the consequences of various policy decisions. However, this approach may also be deceptive, because it requires making assumptions about the way in which people may behave.

Consideration of multiple use of marine resources will be an increasingly important subject in the future. It would seem likely that there will be many conflicts of individual resource interests and rather few comprehensive schemes for resource management. Even within a single nation there are a surprisingly large number of institutional and jurisdictional problems to be resolved before multiple-resource use planning can be a reality.

The increasing development of the world's resources has also underlined the fact that use of land and freshwater resources has great impact on the marine environment, especially in estuarial areas. The dynamics of production in estuaries is complex. In general, estuarial areas are characterized by high productivity because rivers augment concentrations of nutrients either directly or by their effect on oceanic circulation. When land uses change river properties (e.g. quantities of nutrients, silt load, temperature, or regime of flow), there are associated effects on marine production. Unfortunately, there are relatively few comprehensive and well-documented studies on which to predict the effects of changes in river ecology on marine coastal ecology. Most present concern is based on conjecture, and on assumed correlations between events that have taken place in rivers and in the sea, either at the same time, or shortly afterward. There is great need for intensified research on the biology of estuaries.

Rivers have also been used historically as the most convenient sewer system for industrial and human waste. Aside from impacts on freshwater organisms and on anadromous fishes, it is now appreciated that there may be many effects of the indiscriminate use of the ocean as the ultimate sink for wastes. For example, the insecticide DDT and chemically related PCB's are stable compounds. They have been used in large quantities in many parts of the world and a proportion of what has been used has been carried into the oceans. They become concentrated at the top of food chains in fishes that are most commonly harvested for human consumption. It is difficult to know what the final impact of these compounds will be on marine fish resources. It has been demonstrated that DDT influences the nervous system of some fishes and probably impairs normal physiology and behavior. It becomes concentrated in fish eggs and reduces their potential for survival. There are similar effects on marine birds: the egg shells are thinner and eggs are less likely to produce viable chicks; behavior of parent birds may be impaired. Hopefully, the DDT story is unique, but all discharges of complex organic compounds should be viewed with concern.

Recently, considerable concern has been expressed about effects of mercury on marine fishes and on people who eat fish. Waste mercury is a common by-product of many kinds of human activity. Ultimately, much of this mercury finds its way to the sea, and it is especially concentrated in estuarial areas. Much of the alarm generated about mercury contamination appears unjustified. Mercury is a common element in the sea; in many parts of the oceans mercury from natural sources becomes concentrated in fish at the upper ends of food chains. It does not appear to impair normal activities in the concentrations in which it is found. The flesh of these fish would have toxic effects on humans only if it were eaten almost to the exclusion of other kinds of food. It is nevertheless important to appreciate the basic point that man's activities on land can have substantial potential impacts on the resources of the oceans, particularly those in estuaries.

It seems increasingly likely that the awareness generated in recent years will eventually lead to a new pattern of management in which land, the rivers that drain it, and the estuarial areas into which rivers flow, will be considered as an entity. There will, of course, be even greater problems of achieving comprehensiveness than for either land areas or marine areas taken separately. The development of techniques for these kinds of studies will undoubtedly take many years. Ultimately, however, because the natural systems involved comprise an integrated totality, it is obvious that it will be necessary to treat them as such if management is to be successful.

Aquaculture Potentials

The development of aquacultural techniques has a long history, with some notable successes and failures. Small freshwater ponds can be managed to produce high yields almost at the spot where their protein is most needed. Moreover, they can be drained, fertilized, stocked, and variously manipulated to be virtually as effective producers of food as land under the better agricultural practices. But once water bodies reach the size of small lakes, they begin to pose many of the problems of fisheries management of complex ecosystems. However, they may still produce large crops and serve a valuable purpose in water conservation and management. The phenomenal increase in water impoundments has undoubtedly resulted in great increases in freshwater fish production throughout the world. Large-scale impoundments have brought about a great variety of special problems from the fisheries viewpoint: blocking the migratory movements of anadromous and stream species; the explosive but unsustained increase in fish production following impoundment; and social problems such as developing a cadre of fishermen, relocation of displaced persons, and marketing difficulties. However, it remains true that fish production has been increased, often in strategic places, and ultimately these new potentials will be exploited. Indeed, there remains a large potential for further increasing freshwater fish production.

Marine aquaculture has largely been concentrated on a small number of species that are robust and marketable. There are many current attempts to develop production procedures for desirable species, and it seems only a matter of persistence until the list of cultivated marine species is greatly lengthened. The logic of these operations, which concentrate marine production into desired food chains, seems indisputable in the long run. Such operations should increasingly contribute to world fish production.

Enthusiasm for aquaculture should not, however, be pushed to the extreme of expecting rapid development comparable to that achieved in agriculture. Culturable marine organisms are cold-blooded and do not have the extreme environmental tolerances of the common domestic animals. Little is known of the potential for development of genetic strains of marine organisms. Knowledge of their diseases and nutritional requirements is rudimentary. There has been only limited experience of the logistics and economics of marine aquaculture as a food producer. In brief, aquaculture has a long way to go before it contributes substantially to the human food supply.

Contemporary Fisheries Management

The present level of exploitation of existing fisheries seems to be approaching maximum sustained yield. In many coastal fisheries, maximum sustained yield of some major species has been exceeded. If present rates of fishing in these areas are maintained, any gains from the developing fisheries in new areas may only serve to maintain the present total level of harvest. Increasingly, there are fewer unexplored areas in the world's oceans. Most of the potentially large and economically viable fisheries have probably been discovered, are in the process of development, or have already matured at least once into stabilized fisheries. Others are in minimally constrained state of transition to the "ultimate" fisheries for residual species than can support the most intense levels of harvesting.

Currently, estimates of the permissible sustained catch from the oceans range from 100 to 200 million tons per year. With the present catch probably exceeding 70 million tons, and with fishing power still increasing vigorously, there is evident urgency to intervene successfully in the largely unmanaged fisheries of the world.

The present set of devices to accomplish these ends is essentially a patchwork of national, binational, and multinational agreements, supported by only the most general principles of international status. There is no provision, for example, in international agreements to prevent Peru from conducting a high-seas fishery outside Canadian territorial waters for Pacific salmon of Canadian origin; nor is there any international law to prevent Canada from fishing in the Mediterranean. The present structure of management agreements relies heavily on the circumstances of the moment, and the various agreements would undoubtedly take quite different form if there were major rearrangements in the world's economy. There is no rule, for example, that Japan should be a major fishing nation while Madagascar should not. The length of coastline of a country does not necessarily correlate with its share of world fishery resources. Essentially, all nations have an equal right to participate in fisheries that are beyond narrow coastal zones. Conversely, any nation or group of nations can declare an exclusive coastal zone of any width and then try to enforce it.

In brief, contemporary fisheries management is characterized by improvisation. It is guided by no other principle than the current conveniences of national interests. Interventions are thus likely to be many, varied, conflicting, and ineffective, which means that the world's fisheries are at present "managed" with varying, and usually indifferent, success. The course of nonmanagement is only slightly deflected.

An underlying contributing factor to this state of affairs is the uncertainty of our predictions. For the most part the fisheries manager works within technological, social, and economic conditions that are generated by the fisheries. We observe the effects of an "uncontrolled experiment" and there are always opportunities for conflicting interpretations of the collected data. If we are to be more scientific in order to be more certain, it is necessary to specify the ways in which a fishery should be operated. Much of our present understanding would be greatly enhanced by planned programs for extreme fluctuations in fishing effort. The potential loss of a year's crop, or the dislocations of industry, would be amply offset by convincing demonstration of the effectiveness, or otherwise, of our precepts of management. From a purely technical point of view, our understanding of the impact of harvesting is inadequate for the task of management. If we are to advance, it will be necessary to invest heavily in interventions designed to yield knowledge.

The potentials of aquaculture may be great, particularly for producing protein foods at the places where they are needed, or for producing luxury seafood items. It is nevertheless important to stress that aquaculture does not promise to be as easy to develop as a food producer as is agriculture. Investigation, experiment, and expensive trial and error experience are essential as a prelude to large-scale artificially controlled aquatic food production.

Future of Fisheries Management

Given the contemporary state of fisheries management, one can scarcely be optimistic for management in the future. Technological improvements are inevitable. There is no present basis for limitation of fishing power. There is insufficient understanding to speak confidently of consequences. In these circumstances, it seems inevitable that, despite efforts to intervene, there will be little sustained success and fisheries will proceed more or less as if they were not managed. If this is the prospect, there are several possible major policies from which to choose. One policy is to recognize the large measure of futility of present intervention, to abandon international conventions (except as they can be defended by small groups of nations against others), and in this way to hasten the inevitable by acceleration of the transition period when, for economic reasons, the quality of gear and the number of fishermen will be adjusted to the maximum sustained yield. In this process there would be major changes in the relative abundance of various species of fish, in some cases only temporary, but in others lasting a long time. There might also be a period of widely oscillating yields and species composition that would place a premium on the mobility of fishing fleets, flexibility in marketing and processing, and durability of fishermen. It could be argued that a deliberate policy of nonintervention is preferable to other alternatives, but in the present state of knowledge of aquatic communities it would appear to pose risks of creating overfished stocks, not readily restored.

A second policy is to consider radical kinds of international agreements to give an entirely new basis for resource management decisions, with the prospect of successful intervention. For example, it has been suggested that the oceans might be divided up and assigned to different countries for management. Most countries would have a share of that area adjacent to their shores. Presumably, the noncoastal states, such as Switzerland, would be given some share on the grounds that, as citizens of the world, they should not be penalized for not having a coastline. This type of suggestion is scarcely to be taken seriously because the fish would not observe the national oceanic boundaries should they be agreed upon.

A third policy, which deserves more serious attention, is the suggestion that all marine resources should be assigned to international ownership and that the harvest in each part of the oceans should be annually auctioned off to the highest bidder. The number of fishermen and kind of gear used to take the harvest then becomes a question of national business. If the harvesting is inefficient, the country concerned will presumably pay for it economically and, equally, be prepared to do so when it bids. This proposal has some appeal because it does not, by inadvertence, dictate the social and economic value judgements of individual states. It has the disadvantage of requiring the development, very rapidly, of large international machinery, the operation of which is hard to visualize. The problems seem to be greater for coastal than for the pelagic fisheries, therefore it has been suggested that the logical first step is to organize an international auction for the harvest of such species as tuna.

Although this proposal may not be taken seriously in its literal form, it contains the germ of a fundamentally good idea. Essentially it says we should address ourselves to the question, "How would the marine resources of the world be managed if the world were just one country?"

The answer to this question is that we would probably pay most attention to those who are most concerned with each particular resource, and this answer suggests a fourth possible line of action. Though it can be argued academically that Peru may fish for salmon in the North Pacific, the prospect is unlikely. The cost advantages in working from that base would have to be large to offset the disadvantages of such a long trip. The business of catching salmon may thus be confined to the North Pacific coastal states. The same line of argument would suggest that most fisheries are in practice the concern of only a small number of states. What is needed, then, is not a global agreement on fishing, but a pattern that can be followed by interested parties in multilateral agreements. The regional consortia now being formed represent the first steps in such a process.

Multilateral agreements have been in use long enough for some elements to be accepted by many fishing nations. As a bare minimum, the following points should be acceptable: mutual exchange of statistical and scientific information; machinery for consultation and negotiation whenever there are differences in points of view; and recognition of an exclusive or preferential fishing zone of a coastal state.

The width of an exclusive or preferential fishing zone is essentially a political or economic question, there being no single recipe for various species or even for the same species in different areas.

Beyond these basic points there are many avenues for successful multilateral management of fisheries. The most crucial step is acceptance of the principle that the total catch should be limited. This goal is technically much simpler to achieve than regulation of total effort. If there are no national quotas, the catch is taken by the most effective fishermen, and this may appeal to the participating nations as a fair contest. Where there are over-riding reasons for limiting competition, some form of national quotas may seem desirable. In the short run quotas restrict competition, but this is perhaps more acceptable where major dislocations of economies might otherwise occur.

In the decades ahead competition for fish will intensify and, because investments in fishing power will be increasingly less rewarding, there will be some economic adjustments. In this process some stocks of fish may be overharvested, but there is little likelihood of large-scale collapse of fish-producing potentials. As the competition increases, multilateral fisheries agreements can be expected to proliferate, and will consolidate the interests of coastal states that have the advantages of geography and an exclusive or preferential fishing zone. There should be increasingly responsible management and implementation of schemes of limited entry. Multinational firms will increasingly find investments in coastal states more rewarding than distant fishery operations. In these circumstances the prospect is for a difficult transition to more stabilized world fisheries, a transition in part a product of nonmanagement.

The foregoing might be called a conservative view of the future. There are several more imaginative possibilities that may perhaps be explored two or three decades hence, e.g. society may not be best served by considering fisheries problems in their narrow contexts. Even a maximum sustained yield may not be the best objective for management to pursue, because it may be inadequate in satisfying social needs. Thus, recreational fisheries in some parts of the world are heavily subsidized and their management is essentially aimed at providing satisfaction – a commodity notoriously difficult to evaluate. Many inland and coastal fisheries may in future be managed primarily for recreation, because of widespread acceptance of the view that some kinds of recreation are worth more than a protein crop. In some way it may be socially more acceptable to preserve some artisanal fisheries to provide ways of life that many people find desirable despite their technological futility.

At an opposite extreme, other fisheries have yet really to tap the rich potentials of technology. Given the single-mindedness of space programs, it should not be difficult to develop some awesomely efficient techniques of harvesting marine resources. Nuclear power potentials could be used to circulate patches of ocean and produce local plumes of high productivity. Large-scale effects on local oceanography could be achieved by major constructions (such as a dam at the Strait of Belle Isle, with an impact on the Gulf of St. Lawrence). Both ways of life might be realized — programs preserving inefficient methods of fishing because of their social values and programs aimed to develop extraordinarily efficient methods of wholesale harvesting of aquatic resources. This kind of combination is sufficiently paradoxical to sound typically human. The parallels to worldwide practices of land management are striking, for there, too, the trend is to efficient mass production of food and fiber, and setting aside parks and reserves.

In some respects marine environment and communities are less susceptible to human abuse than is the land environment, and may ultimately provide much more human food than now. But the food-producing capacities of man-controlled oceans may never be fully developed. There is a growing opinion that full realization of the world's food-producing capacity may well be synonymous with such a dreary existence that for this reason, as well as others, steps will be taken to ensure adequate restriction in the growth of the human population.

Scientific Advice to Fisheries Bodies[1]

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LUCAS, C. E. 1973. Scientific advice to fisheries bodies. J. Fish. Res. Board Can. 30: 1958–1964.

New fisheries require immediate order-of-magnitude estimates of potential sustainable yield, obtainable from echosounder surveys, catches of eggs and larvae, or even from primary productivity. As fishing develops more precise estimates are needed based on catch, effort, size and age composition, and the application of a suitable production model. Predicted levels of sustainable yield must then be checked against the performance of the fishery, and eventually the effects of environmental variability must be brought into a predictive equation.

Systems for providing scientific advice by international working parties have been evolved in the more mature regional bodies, and are being adapted to the circumstances of the newer ones. Requirements are that their conclusions and predictions should be timely and expressed as simply as possible, and made fully available to all countries concerned. Neutrality and credibility are vital.

These requirements of the scientists, in their international capacity, imply responsibilities for the Commissions to secure the best available scientists and a timely production of data by member countries, and to take timely decisions in the light of the evidence and predictions available.

In the newer Commissions, and for fisheries where no regulatory body exists and scientists are few and inexperienced in collaborating internationally, aid on a broad scale is essential. This aid must come ultimately from the developed countries, sometimes directly and sometimes indirectly, via the regional or global body of which they are members. FAO and its COFI have a major role to play here; they, like the regional bodies, must be provided with funds for the requisite central staff, support services and facilities, and for mounting the necessary international working party meetings.

The Department of Fisheries of FAO with its associated regional bodies is in a unique position to correlate fishery experience from different parts of the world, and to disseminate it wherever needed.

La création de nouvelles pêcheries exige que l'on procède immédiatement à des estimations approximatives du rendement constant potentiel, en se fondant sur les résultats d'enquêtes par échosondage, des captures d'oeufs et de larves ou même de la productivité primaire. A mesure que les opérations de pêche se développent, on a besoin d'estimations plus précises fondées sur les prises, l'effort de pêche, la composition par taille et par age, et l'application d'un modèle approprié de production. Les prévisions relatives au rendement constant doivent ensuite être comparées aux chiffres réels, et enfin les incidences de la variabilité du milieu doivent être traduite en une équation prévisionnelle.

Dans le cas des organismes régionaux plus anciens, on a élaboré des mécanismes par lesquels les groupes d'études internationaux pourraient donner des conseils scientifiques, mécanismes qu'on adapte actuellement aux besoins d'organismes plus récents. On voudrait que les conclusions et les prévisions de ces organismes se fassent au moment opportun, qu'elles soint exprimées le plus simplement possible et qu'elles soient mises à l'entière disposition de tous les pays concernés. La neutralité et la crédibilité sont des éléments essentiels.

Etant donné ce que l'on attend des scientifiques, en rapport avec leur rôle international, les commissions doivent trouver les meilleurs scientifiques disponibles, amener les pays membres à fournir les données à temps et prendre des décisions opportunes à la lumière des données et des prévisions dont elles disposent.

Dans le cas des commssions nouvellement formées et des pêches qui n'ont pas d'organismes de réglementation et où les scientifiques sont peu nombreux et sans expérience en matière de collaboration internationale, une aide à grande échelle s'impose. Cette aide doit, en définitive, venir des pays développés, parfois directement et parfois indirectement, par voie des organismes régionaux ou internationaux dont ils sont membres. La FAO et son Comité sur les pêches ont un rôle important à jouer dans ce domaine; ces derniers, comme les organismes régionaux, doivent obtenir les fonds qu'exigent un personnel central, les services de soutien et les installations, ainsi que la tenue de réunions internationales pour les groupes d'étude.

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

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Le Départment des pêches de la FAO et les organismes régionaux qui collaborent avec lui se trouvent dans une position priviligée pour réunir les résultats d'expériences halieutiques provenant des différentes régions du monde et les diffuser partout où cela est nécessaire.

Las nuevas pesquerías necesitan estimaciones immediatas de la magnitud del posible rendimiento sostenido, que se obtienen mediante reconacemientos con ecosondas, capturas de huevos y larvas o incluso a partir de la productividad primaria. A medida que aumenta la pesca son necesarias estimaciones más precisas basadas en las capturas, esfuerzo, composición según talla y edad, y la aplicación de un modelo de producción adecuado. Hay que comparer los rendimientos sostenido previstos con el resultado de la pesca y, por último, deben incorporarse en una ecuación predictiva los efectos de la variabilidad del medio ambiente.

Los organismos regionales más antiguos han desarrollado sistemas para ofrecer la opinión científica de grupos internacionales de trabajo que los organismos más recientes están adaptando a sus circunstancias. Sus conclusiones y pronósticos deben ser oportunos, expresados del modo más simple posible y puestos a disposición de todos los países interesados. La imparcialidad y credibilidad son elementos fundamentales.

Estos requisitos exigidos de la capacidad internacional de los científicos hacen que las comisiones adquieran la responsabilidad de obtener los mejores científicos disponibles, la preparación oportuna de datos por los países miembros y la toma de decisiones pertinentes a la luz de las pruebas y pronósticos disponibles.

En las Comisiones más recientes y en el caso de pesquerías en que no existe un organismo regulador, y dispone de un número reducido de científicos sin experiencia en la colaboración internacional, se considera esencial la ayuda a gran escala. En última instancia, dicha ayuda debe provenir directa o indirectamente de los países desarrollados, a través de los organismos regionales o mundiales de los que son miembros. La FAO y su Comisión de Pesquerías (COFI) tienen aquí un papel muy importante a desempeñar y, al igual que los organismos regionales, deben recibir los fondos necesarios para disponer del personal administrativo y de las instalaciones y servicios de apoyo necesarios para organizar las reuniones necesarias de los grupos internacionales de trabajo.

El Departamento de Pesca de la FAO, con sus órganos regionales asociados, está en condiciones únicas para correlacionar las experiencias pesqueras de diferentes partes del mundo y para difundir la información donde sea necesaria.

I shall begin by expressing a personal belief – that, as far as possible, "problems" should be solved at the national level, and only those that cannot be solved thus be taken at the regional level. Correspondingly, the latter should desirably be solved at that level and only those of a further-reaching nature be taken for discussion at the world level. There is both sense and economy in this, and it has implications for the scientific advice that such problems need for their solution. This belief carries no implication that scientific understanding is or should be restricted; it usually is relevant over a wide, often a global, field. It is significant that the International Council for the Exploration of the Sea (ICES), an international organization concerned with acquiring understanding, was established long before most of today's international fishery bodies, although the knowledge it has acquired has had wide application and has stimulated the birth and fed the growth of several of them.

The organized provision of scientific advice to fisheries bodies has pioneered a movement that now promises to be of the greatest importance. In recent years we have faced problems that were scarely anticipated within those ocean regions of common property and interest. While fisheries still give us the greatest yield from the oceans, other resources are catching up, and more will follow. At least as important, we now appreciate the importance of the health of the oceans, and the risk that it may become endangered. For these and many other marine interests, important international decisions have to be reached, and wise decisions can only be reached in the light of scientific advice. Today we are concerned with fisheries science, and how to secure the best advice for the best assessment of future risks and benefits, strategy, and policy. Such is the basic unity of science and the web of relations within the ocean that much of this fisheries pioneering will be relevant over a far wider field. Marine scientists have a heavy responsibility and fisheries scientists may have much to contribute.

Nowhere is this more evident than in their recognition of the dangers of the rapid changes in fishing processes that have occurred during the last 10 years. Up to the 1950s, changes in industrial technique and development were slow enough for reasonable evaluation before effects on the stocks became really serious. Even in 1966, when I had the privilege of addressing the first COFI meeting on "Fisheries penalties and rewards," I was still hopeful that, with increased support, fisheries scientists could keep up with the rapid pace of technological change, and I must still be hopeful. But the dangers were evident then and the pace has increased since then, especially as regards the rapid deployment of fleets of specialized vessels from one stock to another. With "pulse fishing" the rate of change has increased greatly, and now other threats are developing, such as pollution, demanding more intensive study of fish, their food, and their environment. The environment is naturally variable, but now we risk an increased and directional rate of change. Meanwhile, the imminence of the second Law of the Sea Conference underlines the need for rapid mobilization of knowledge and draws attention to other responsibilities and opportunities; for these, new arrangements will have to be made and additional data provided for analysis by scientific methods. It is expected that both pollution and research will appear as specific items on the agenda.

Essential Kinds of Advice

The essentials of the scientific advice on which fisheries regulation must be based are much as they were 20 years ago. These are a detailed knowledge of the biology of the stocks being fished (especially the characteristics of their distribution, and growth, reproduction, and mortality rates), the catches being taken, and the biology of marine organisms that, as food and predators, affect them. This means understanding far better the complex relations of the ecosystem in which the fish live, and continued monitoring before and after regulation.

Scientists have a fair knowlege of the biology of several fish, and can devise models to predict the effects of different rates of fishing and, most important for regulatory bodies, the likely effects on the stocks of regulations affecting these rates. But for many fish our knowledge is scanty, while no advice is complete and predictions are really probabilities. This is partly because of imprecision in the raw data and inadequacies in the models, but also because of ignorance of the effects of intense fishing on stock recruitment, as well as those of varying food and predation, and of variations in the natural environment in the circumstances of a particular fishery and year. Although scientists can give valuable advice in terms of yield per recruit, natural variations are from time to time dominant, while man's influence on the environment is steadily growing. But more immediate is the impact of the mobile fishing fleet, which can hit a stock heavily and quickly switch to another of the same species, or to a different species, within one season. Thus, the scientist has less time to evaluate effects and predict results, and fishing countries have barely time to supply essential data, even when they try to do so. The whole is complicated further when a commission's region is invaded by the fleet of a major fishing country that is not or cannot be a member, or when a fishery is developed so suddenly that there is no organization to deal with it, perhaps in an area where there are few or no scientists to evaluate the data.

MORE RESEARCH NEEDED

Several things are clear. First, more and better-organized research effort is necessary to acquire three kinds of information:

Essential data regarding all stocks of commercial interest are needed, not only after they have come under heavy pressure or are overfished, but when they are lightly fished or even unfished. Others will define these data more precisely but for existing fisheries they comprise timely statistics of total catches of the relevant stocks and their size compositions, and precise data regarding the fishing effort being applied to them, with supplementary data regarding growth, distribution, and movements. For recently developed and future fisheries, cruder methods will have to serve, from exploratory fishing surveys to evaluate standing stocks to egg and larval surveys, or even basic productivity data. Some estimate of their potential is essential if dangers met by more mature fisheries are to be avoided, or if we begin to tap the oceans' resources of smaller forms, such as krill.

In particular, timely data (on either a national or company basis) is needed from the massive mobile fleets of today, with appropriate teams of scientists to assess the data as they emerge week by week, if not day by day, through the season. Even so, there must be the will within the relevant commission not only to reach decisions on the first reasonably reliable estimates from the scientists, but also to recognize a decision not to regulate is a step with consequential effect on the fishery.

A far better understanding is needed of the biology and physics of specific fishery ecosystems. These may be seen most simply as lying within the range of the current system that encompasses the stock in question, and the pollution risks that characterize that system. There is much to be said for studying the dynamics of pollution and of fisheries exploitation together; problems already met in allocating the yield from fisheries will doubtless be met again in dealing internationally with pollution. In particular, we need a system for regular monitoring of dangerous pollutants in the fish themselves, and in their products, so that appropriate action can be taken, and their release regulated.

It is dangerous to continue to expand a fishery when one does not understand what is happening, and this brings me to the commission that needs advice; and also to the circumstances in which there is no regional body, and only FAO in the background. Although there appears to be a regional body over most of the world's waters, it is far from correct to think that all fish stocks are regulated or under investigation. Only in the North Atlantic and Pacific Oceans, from which most of our experience has been gained, is this approximately so. What then has been achieved, at the best? First, some regulation of minimum fish sizes and minimum mesh sizes, especially in the North Atlantic; and the limits of this kind of regulation have been reached or can be forseen, especially when more than one kind of fish is being sought. Further it is becoming recognized that neither of these alone, nor restrictions by season and area, can save a stock from overfishing; any benefits induced become incentives to increased fishing or attract fishermen from nonmember countries.

The chief problem facing all commissions is to control the total amount of fishing, usually by limiting total catch. This is reasonably simple in scientific terms, when the statistics, central facilities, and qualified staff are available and a rough prediction of the maximum sustainable yield can be made: in classical cases appropriate effort is so much less than that being applied that any reduction would be an improvement, desirable in both biological and economic terms. Even within relatively mature commissions, however, two more problems have arisen: delays in reaching decisions, allegedly on account of the uncertainty of scientific advice provided; and, when a decision is reached to restrict fishing, the problem of how the resulting yield shall be allocated (with the related problem of newcomers). An associated danger has been that the prescribed total, though not exceeded, may not be taken in the most economic manner (e.g. a large fishing effort may be applied over only a small part of the season or stock).

REDUCTION OF CAPITAL AND LABOR

It should be relatively easy, when fishing is on only one species, to restrict the total amount of fishing within a commission's area and to allocate the yield in principle, and some bodies have already taken these steps; but it is more difficult to lay off either the financial capital represented by boats (e.g. in whaling) or the human capital of experienced fishermen. The solution has usually been that the excess effort is directed elsewhere, and for many years this was not only a safe outlet but a valuable one in leading to an increased yield from a replaceable resource. More recently, the danger has been that the effort is directed, not to a new or underfished stock, but to one under pressure or near its maximum sustainable yield, as has been the case in the northeast and northwest Atlantic. In this "well-developed" instance, where the scientists were experienced and in close touch, the problem was anticipated and the two commissions involved benefited by coming closer together, through the common interest of scientists, administrators, and fishermen. It is no easier of solution, however, and the potential danger, being worldwide, points to the urgent necessity for a mechanism such as FAO provides, with its Committee on Fisheries, which would keep all concerned in close touch.

Responsibilities of International Commissions

Each of these problems demands two things for its solution that are the prime responsibilities of the commission. First it needs facts, and advice about these facts and their implications; second, it needs a determination to ensure that the advice provided is the best available and to act upon it. This problem of acting in good time I leave as a warning, but perhaps it is not always appreciated that commissions are primarily responsible for the advice they get!

Commissions have had two main means of securing scientific advice: by the organized cooperation of scientists of member nations; and by employing their own staffs. Details concerning the use of these two methods have been published by FAO. In either case, national scientists are ultimately involved. These are, or should be, the source of advice on the wide range of problems that can be tackled at the national level; they are also required by governments to provide guidance in assessing the pros and cons of following international scientific advice laid before a commission.

Taking ICNAF and ICES as examples, national scientists are drawn on for international committess and working parties. However, they are necessarily also the normal source for recruiting to established central regional staffs.

Again, essentially national information must be provided and assessed, if only to ensure that governments appreciate its significance, but the quality of the conclusions and international advice that will emerge will be directly relevant to the ability and integrity of those scientistis who are at the forefront of their subjects. It is the responsibility of the commission members to secure the best available scientists to provide advice, whatever their nationalities. This responsibility should not be shirked by leaving matters to chance and laying the blame for any deficiencies on insufficiently qualified or inexperienced scientists. With this important responsibility goes the duty to ensure that the scientists have the support and resources (information and data centers, computers, etc.) and the authority to conduct their investigations in all the relevant waters of the Commission's area – in fact, the freedom to conduct their investigations properly.

STATISTICS ARE ESSENTIAL

The essential bases for scientific advice are, in addition to the "capital" of previous research, the raw statistics of the fishery in question. For prediction models to be derived from them speedily it is essential that governments collaborating in regional commissions ensure the timely production of raw catch statistics for every stock of commercial interest. While scientific advice will be helpful in doing this, the requirements have been clearly spelled out by more than one commission. Then, scientific investigation, and much more of it, is required to supplement these raw data with those essential for determining stock composition and vital statistics for stocks being fished heavily and those likely to be fished. These are tasks for fishery scientists proper. It will also be largely their responsibility to determine the more obvious effects of fluctuating food supplies and of predation, and perhaps of other and more subtle ecological relations, but they will be seriously handicapped if they are not well supported by the investigations of other marine biologists with a keen appreciation of the significance of many of their ecological studies for furthering fisheries science. Similar collaboration and understanding is needed from the fields of physical oceanography and meteorology, without which fisheries scientists will probably be unable to provide more than inspired guesses about the effects of the environment on fisheries in individual seasons.

INCREASED SCIENTIFIC RESOURCES

Thus more research is needed to determine the effects, to assess the rates, and to evaluate the probabilities of the results of natural processes and the effects on them of fishing and of factors such as pollution, and also the effects of attempts to regulate fisheries. Fortunately, these increased scientific resources are not needed equally over the whole field, although they are not yet sufficient for the task in the most developed countries and mature commissions. They are, however, woefully scanty or lacking in many countries and commissions, and by no means all fisheries are supervised adequately by commissions or governments. Even if funds were available, suitable scientists still have to be trained, and the assistance of the developed countries will be essential if the developing countries are to be staffed to investigate their local resources and to collaborate with, and debate findings with, the scientists of the developed countries which so often share or initiate fishing off their shores. It must be the responsibility of the developed countries, in cooperation wherever their fisheries operate, probably through FAO and its Committee on Fisheries, to ensure these facilities for the developing countries.

EXAMPLE OF THE INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

The solution to assembling the facts and knowledge required to support fisheries science is less easy to specify, since it requires collaboration between pure and applied scientists, usually nongovernmental and governmental scientists; but the range of investigations between pure research and applied research and development is continuous and few scientists these days have no desire to see their work usefully applied. A possible solution lies in the Intergovernmental Oceanographic Commission (IOC) of UNESCO, which has made arrangements to secure scientific advice from several sources (governmental, nongovernmental, and industrial), including the Advisory Committee on Marine Resources Research of FAO, and is being supported as well as by its parent body UNESCO, by FAO, WMO, IMCO, and the UN itself, through the agency of the Inter-Secretariat Committee on Scientific Programmes Relating to Oceanography (ICSPRO). This is because each of these bodies considers that some of their research objectives might be achieved through the coordinated efforts of the 70 governments collaborating as members of IOC. With the aid of these several advisory bodies, IOC has recently formulated its Long-Term and Expanded Programme of Oceanographic Research which includes several fisheries projects, and its Global Investigations of Pollution in the Marine Environment, both of which found considerable approval last year at the Conference on the Human Environment in Stockholm. If IOC is to go further, however, ICSPRO has much further to go, and IOC is concerned about this, as were those meeting in Stockholm. But this body is a first step in beginning to identify and unify the common marine interests of a number of UN agencies supporting pure or applied research, and out of the ICSPRO concept could come the international collaboration over the field of oceanography that will be as essential to other applied marine sciences as it is to further progress in fisheries research.

Communicating Results of Research

I have been looking a little into the future to foresee likely ways of developing research, but there remains the recurring task of formulating and presenting the results of research in ways that shall be acceptable to, and compel action, by the commissions. Events have shown that this is as important as the research itself. Its importance is underlined by the hesitation commissioners have often shown to adopt advice, and by the eagerness with which commissions have sometimes used scientific hesitation and uncertainty (despite the requirement that they seek scientific advice) in order to delay action when delay was convenient, though not advisable. What are the basic requirements?

They are that the science shall be as adequate as contemporary knowledge permits, and that it shall be seen to be good by the national scientists concerned and their colleagues in other countries, and by administrators in commissions. This implies the fullest explanation and dissemination of the results of science. Take as an example what I believe to have been the most successful, the North Atlantic commissions, which ultimately are similar in obtaining advice from working parties, organized in the case of ICNAF by its Research and Statistics Committee and in that of NEAFC by ICES and its Liason Committee.

Perhaps the chief feature of this sytem has been that advice has been both sought by the commissioners and proffered by the scientists, especially in ICES. It is important that this tendency should continue, despite the desire for governments to tell their scientists what to do and when to do it! Another feature, especially under ICES, has been a strong tradition of international laboratory cooperation and of bringing to bear on marine and fisheries problems the investigations of academic marine laboratories as well as governmental fisheries laboratories. This has been a good thing and I hope it will continue, for only in this way can the whole range of contemporary marine understanding be available and directed to the solution of fisheries problems. And for this to be successful it will be necessary for there to be more effective collaboration at sea than has sometimes been achieved or possible in the past.

Scientists then have the responsibility of providing up-to-date answers to questions posed by the Commission, and must continue to proffer constructive and imaginative guidance to meet anticipated development and management needs. Whatever the problem, the essentials have always been for the scientists to bring together all the available evidence so that it can be discussed and assessed, usually in an ad hoc working party, in order to provide, well ahead of the Commission's meeting, an agreed report. An essential is to eliminate any suspicion of bias and, while remarkable success has been achieved in neutrality towards national interests, the task of the Chairman of such a group is not an easy one. Owing to recent developments, such as extension into areas where scientists have not been used to working together, it is not going to be any easier. Yet ultimately the credibility of scientists and of science is at stake for, if they cannot reach constructive agreement, it will be difficult for the commissions to do so.

Of what then does agreement consist? Not on meaningless agreement at the lowest level, where national interest disappears because awkward facts have been shelved and serious argument has been avoided. Traditionally, science is neutral but, while the neutrality should be made evident by all scientists, this has not always been credited, and they must often also be viewed as nationals. Sometimes agreement about what may appear to be the truth may simply be impossible. In the most mature commissions these problems have usually been overcome by the experience of scientists and governments that have worked together before, and have learned that the truth is the only useful objective, and is in everyone's interest. Agreement can be reached on the data available and then on conclusions and implications, once it is realized that any report that cannot be clear-cut in its conclusions must set out clearly what the alternatives are, whether they arise from apparently incompatible data or are alternative deductions from those data. When a report is presented on the basis of such clear beliefs, then the Commission is as well armed to reach decisions as is possible.

I have tried to deal with the problems of neutrality and reaching agreement, at least in older commissions. But how neutral can the scientist afford to be? He will have at least some convictions to guide him. All research is motivated, but fisheries scientists should be ecologists, and ecologists are concerned with relations between organisms and their environment. Although facts are accumulating and some principles are emerging, ecology is the most complex science and we have far to go. Accordingly, fisheries scientists, like all ecologists, must be modest about what they can predict. There is still no certainty, only probability.

Most ecologists subscribe to a code derived from their studies, and to those like Kesteven who have tried to formulate a code consciously, it contains elements that are guidelines for all of us. Perhaps the most important element is that "the objectives of the community (and, hence, of Government) with respect to resources should be to control and direct the use of resources and interference in resource systems so as to obtain the maximum short-term and long-term benefits," and that "every resource-use project should include appropriate restorative or compensatory measures." This requires great understanding, but it is dangerous to prosecute and expand a fishery without understanding what is happening. The necessity for such understanding is part of the marine scientist's code; he has an associated responsibility, as Holt has pointed out, of observing and reporting on what is happening to the oceans, both before and after exploitation and regulation. Often he alone is in a position to do this. I believe it is these two elements that explain why fisheries scientists have frequently been ahead of governments in exposing problems and in finding at least interim solutions for them.

Although practical and well tested by now, these principles may be self-evident only in the more mature commissions. What of commissions recently established, and those not yet subject to supervision; and what of the fisheries and areas of the ocean where trained fisheries scientists are scarce if not absent? I am sure the principles still apply, though circumstances may differ so that they have to be applied differently. Within the mature commissions it is taken for granted that each member nation has a staff of fisheries scientists, and a commission as in the North Atlantic may need few or no scientific staff, progress being achieved by the stimulus and co-ordination of national activities. In some of the newer commissions, as in several set up under FAO, this is far from so; and in several areas of the oceans fisheries exist although no commission does, and no organized research is in progress. Discussion and regulation may be hindered by national differences that make prospective cooperation difficult. Yet we all must be (and FAO is) greatly concerned about actual or potential fisheries that are parts of a common resource but still unsupervised.

In some instances solutions or potential solutions have been found by one or more countries initially providing the major part of the expertise, or by FAO providing it in one case at least by stimulating investigation and offering advice in conjunction with another body (ICES) not immediately concerned with the fishery in question. Establishment of new commissions should be encouraged, but even more important are arrangements, preferably international, for providing scientific training and financial assistance so that each country with a significant interest in a fishery can begin to assess it and discuss its status and prospects realistically with other interested countries.

Conclusion

Investigation and resulting action should be kept to the lowest level appropriate to the problem in the sequence nation, region, and globe; but this should not be taken as implied criticism of international organization and action, so long as it is reserved for those problems that demand it. So far is this from being the case that I firmly believe that at each level appropriate action has not only benefited but positively stimulated investigations at the lower levels. Thus the needs of the North Atlantic bodies, in attempting to resolve their problems, have stimulated the national investigations of the member states, even the most developed. The needs of FAO and its COFI, in tackling global problems, have similarly stimulated the most mature regional bodies, while they have obvious responsibilities to the developing ones and even greater ones to the undeveloped! Perhaps the greatest of these is in the provision of advice, from data to assessments, whether for guiding the early steps of a newly formed body or, where need be, providing the stimulus to organize a new one. An earlier point I made shows the significant role FAO and COFI may play in coordinating the whole range of regional bodies, not by incorporating them but by helping to make the information and experience of each available to all and taking a wider view than any of them is entitled to take, e.g. FAO might well be able to help when any dispute arises.

But the provision of advice costs money, at every level. It is doubtful whether the resources made available to the scientists of even the major countries are adequate to their tasks, although greater efficiency in exploiting them might make the present funds go further. In many countries they are quite inadequate, both in relation to the problems faced and in relation to the resources at stake; as the late Wib Chapman so strongly believed, the world as a whole makes available quite inadequate resources for investigating and conserving what is still the ocean's major yield. While I am convinced that the effectiveness of international bodies must lie primarily in the efforts of their member countries, the costs of training, of disseminating information, of international discussion, and of coordination and regulation are not inconsiderable; they are great, especially when a substantial part of the membership is in the developing phase. If we are to obtain the maximum short- and long-term benefits from the oceans' living resources, before they have been damaged beyond restoration, then the scientific resources for their investigation must be greatly strengthened. Nowhere is this support more necessary than for the global body, FAO, with its wide responsibilities, and for the regional fisheries bodies dependent on it.

Summary

1. For fisheries in their very early stages, and for future fisheries, it is essential to have as soon as possible some idea of the potential, so that it is not rashly exceeded. To be timely, these may need to be obtained as relatively crude estimates by means of exploratory fish surveys, egg and larval surveys, and even primary productivity estimates.

2. For more mature fisheries, and more precise estimates of maximum sustainable yield, classical data are required concerning catches, size compositions, effort applied, growth rates, distributions and movements,

etc., together with ecosystem studies relevant to food and predators.

3. While classical models are available for estimating maximum sustainable yield, there is need for further research into the most suitable models for particular circumstances, and especially into the circumstances in which intensity of fishing affects not only the stock but also recruitment.

4. Environmental effects naturally vary greatly, in time and space, for good and bad, while man's activities through pollution risk exerting a unilateral and undesirable effect on fish, other organisms and man himself. Much more research at the highest level and, in due course, monitoring are needed if environmental effects are to be incorporated in the models for prediction, and release of pollution regulated at appropriate levels. The active collaboration of scientists from other marine fields is essential; IOC (with its LEPOR and GIPME) has already been recognized by FAO and other bodies as competent to play a vital role here.

5. Systems for providing scientific advice by international working parties have been evolved in the more mature regional bodies, and are being adapted to the circumstances of the newer ones. Essential requirements are that their conclusions and predictions should be timely and expressed as simply as possible, and be fully available to all countries concerned. Neutrality and credibility are vital.

6. These requirements of the scientists, in their international capacity, imply responsibilities for the commissions to secure the best available scientists and timely production of data by member countries, and to take timely decisions in the light of the evidence and predictions available.

7. Above all is the need for monitoring the fisheries and their environment to be maintained after predictions have been made, and regulations applied, both to check on the predicted effects of the regulations and to determine any subsequent changes in circumstances.

8. Even in some of the most mature commissions these requirements have not yet been fully met and there remain needs for strengthening national capabilities and developing international facilities (such as information and data centers and central computer services), as well as for coordinating and disseminating results and experiences inter-regionally. In the newer commissions, and for fisheries where no regulatory body exists and scientists are few and inexperienced in collaborating internationally, specifically among the developing countries, aid on a broad scale is essential if resources are to be exploited rationally, and their scientists enabled to contribute usefully in kind and in debate to international discussion and decision. This aid must come ultimately from the developed countries, sometimes directly and sometimes indirectly, via the regional or global body of which they are members. Here in particular FAO and its COFI have a major role to play and it is necessary that they, like the regional bodies, be provided with funds for the requisite central staff, support services, facilities, and, especially, mounting the international working party meetings required to fulfil its objectives.

I am indebted to various friends, Geoffrey Kesteven, Sidney Holt, John Gulland, and the late Wib Chapman, who earlier ventured to set out their ideas on paper, and I am restricting my references to selected papers by them.

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Dependence of Recruitment on Parent Stock[1]

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CUSHING, D. H. 1973. Dependence of recruitment on parent stock. J. Fish. Res. Board Can. 30: 1965–1976.

Observations on the relation of recruitment to stock suggest that there is a lightly convex curve for herring and a dome-shaped one for gadoid fishes, in contrast to flatfishes where a flat-topped curve is well established for several species. Theoretical examination of potential mechanisms lead to a suggestion that natural mortality rate decreases with age down to a minimum, then increases among the older, senescent, fish. This has been incorporated into yield curves for the North Sea plaice and Arcto-Norwegian cod, which have maxima at rates of fishing (F) of 0.22 and 0.26, respectively.

Les observations faites sur les rapports entre le recrutement et la population montrent que cette relation est une courbe de dôme dans le cas des gadidés et une courbe légèrement convexe dans le cas du hareng, comparativement à la courbe asymptotique nette constatée dans le cas de plusieurs espèces de poissons plats. L'étude théorique des mécanismes potentiels donne à penser que le taux de mortalité naturelle diminue avec l'âge jusqu'à un minimum, puis s'élève parmi les poissons plus âgés ou sénescents. L'auteur a introduit ces données dans les courbes de rendement établies pour la plie de la mer du Nord et la morue arctico-norvégienne; ces courbes ont des maximums qui correspondent à des taux de pêche (F) de 0,22 et 0,26, respectivement.

Observaciones realizadas sobre la relación reclutamiento/reservas muestran que la curva relativa a los arenques es ligeramente convexa y la de los gádidos es de campana en contraste a la de los peces planos que es de tipo claramente asintótico para varias de estas especies. El examen teórico de los posibles mecanísmos mueve a sugerir que el índice natural de mortalidad disminuye con la edad hasta llegar a un mínimo y aumenta de nuevo entre los peces de mayor edad. Se ha incorporado estos datos en curvas de rendimiento de la platija del Mar del Norte y el bacalao del Artico-noruego cuyos puntos máximos se registran con índices de pesca (F) de 0,22 y 0,26, respectivamente.

FISHERMEN have often explained declining catches by saying that death by fishing reduced the breeding stock and hence, by implication, recruitment. However, the earliest formulations of the effect of fishing by Petersen (1894), Garstang (1900), and Heincke (1913) were concerned with the loss in weight by catching fish before they had time to grow. The possibility of reducing recruitment by fishing down the stock was not excluded, but all three authors were influenced by the "small plaice" problem: in the first decade of the present century, British trawlers used to catch very small plaice on their nursery grounds on the coasts of Holland and Germany.

During the 1930s the problem of "growth overfishing" was approached by Thompson and Bell (1934) on the Pacific halibut and by Graham (1935) on the North Sea plaice. The first-named authors developed the relation of stock density to fishing effort and the second applied a form of the logistic curve. A combination of the two methods led to Schaefer's model (1954) in which the logistic curve was applied with parameters extracted from the dependence of stock density on fishing effort. In all three formulations the effects of growth and recruitment are confounded. Each of the authors wrote that recruitment should not decline under the pressure of fishing because it was thought to be inversely dependent on adult mortality, within the fishable range of the stock.

The problem of growth overfishing was solved in the yield-per-recruit formulation of Beverton and Holt (1957). Although they developed a stock/recruitment curve and a self-regenerating yield curve, they were unable to detect any decline of recruitment at low stock in the data available to them (except for the Pacific salmon). The success and simplicity of their solution made it hard for fisheries biologists to concede that fishing could in fact reduce the resilient recruitment.

Between 1955 and 1965 the Downs herring stock declined and with it the East Anglian herring fishery (Cushing and Bridger 1966). Following the effort exerted on the Arcto-Norwegian cod stock during the early 1960s, four year-classes were practically nonexistent in the late 1960s and early 1970s. Cushing (1971) suggested that four great pelagic fisheries had disappeared through recruitment overfishing; they were the Hokkaido herring, the Japanese sardine, the Norwegian herring, and the Californian sardine. Despite the demonstrations that "recruitment overfishing" was a reality, the solution has evaded the scientific search.

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Formulation of the Dependence of Recruitment on Parent Stock

The first explicit formulation of the problem was made by Ricker (1954, 1958) and it was applied to the Pacific salmon, a stock that recruits, spawns, and dies in virtually a single age-group. Earlier, Ricker (1950) had studied the dominance of one of the four-year cycles of the Fraser sockeye and suggested that the smolts of the dominant cycle either ate or competed indirectly with the larvae of its successor. Later, with a simulation model, Larkin and McDonald (1968) showed that the suggestion was probably right. Ricker distinguished density-independent from density-dependent mortality and suggested that the latter was generated by cannibalism or by the aggregation of predators as a function of the initial number of eggs or larvae. His equation can be written in the form:

$$R = AP(\exp - BP) \qquad (1)$$

where R is recruitment; P is stock; A is the coefficient of density-independent mortality, and B is the coefficient of density-dependent mortality. A more general development is given in Paulik et al. (1967).

This equation can describe any form of curve from a near-linear one to one with a marked dome of recruitment. Then Ricker introduced the idea of the replacement stock, which is that for which recruitment and parent stock are equal:

$$R/R_r = W \exp [a(1-W)] \qquad (2)$$

where $R_r = P_r$, the replacement stock; W is P/P_r, and a is P_r/P_m, P_m being the stock at which recruitment is maximal.

Figure 1 shows a family of Ricker curves with different values of P_r/P_m; if $P_r/P_m < 1.0$ the curve is near-linear, and if $P_r/P_m > 2.0$ it is markedly dome shaped.

When $P < P_r$, $R/R_r > P/P_r$; when $P > P_r$, $R/R_r < P/P_r$. In a single-age stock like the Pacific salmon the virgin stock stabilizes about the point of replacement where the curves in Fig. 1 cut the bisector. Two important biological principles are expressed here: first, that the stock must replace itself by recruitment and, second, that the stock can stabilize itself by means of the varying recruitment.

Ricker's developed equation has been used extensively and successfully in the studies of the Pacific salmon; in particular, Larkin's simulations based on it have illuminated the biology of the animal to a considerable degree. It has not been applied to the multiage stocks of marine species because, lacking knowledge of the trend of natural mortality with age, the replacement stock is inaccessible. However, more important, stock is not replaced by a sum of recruitments, but by a succession of them.

The second formulation of the stock/recruitment relation is the first equation of Beverton and Holt (1957). They also distinguished density-independent and density-dependent mortality. However, the latter was considered to last for a limited period during larval life when food was critical; thus it was generated by the density of larvae at some period long after spawning. The equation was written in the form:

$$R = 1/(\alpha + \beta/P) \qquad (3)$$

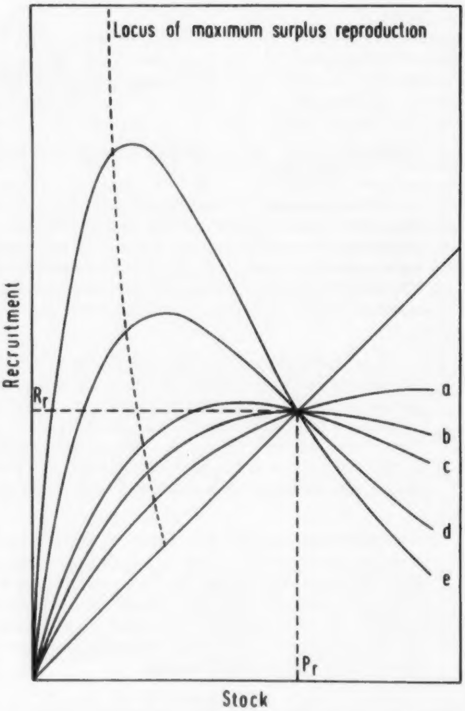

FIG. 1. A family of Ricker curves (Ricker 1958).

where α is the coefficient of density-dependent mortality, and β is the coefficient of density-independent mortality.

Recruitment reaches an asymptote in stock and so it is a quite different expression from Ricker's. When the stock is reduced so far as to reduce recruitment, there is little difference between the two expressions. The real difference between them lies in Ricker's conclusion that there might be a maximum of recruitment, of which account should be taken in management. The conclusion of Beverton and Holt was profoundly different: that no step in management need be taken until recruitment was shown to decline, and by implication that this was unlikely within the fishable range of the stock.

However, Beverton and Holt developed a second equation. They extended the idea of a critical period in larval life to the suggestion of Ricker and Foerster (1948) that larvae may grow through a critical period, t_c, more quickly at low density than at high density. They suggested that:

$$t_c \,\alpha\, \frac{1}{W_\infty} \,\alpha\, \frac{1}{\text{food eaten}} \,\alpha\, \text{density.}$$

An equation was developed, identical in form to equation (1), but the coefficient of density-dependent mortality had a quite different meaning. The curve can be fitted to data with a dome, just as can Ricker's curves. An additional coefficient of density dependence was used to simulate the possibility of cannibalism in their treatment of the Georges Bank haddock data. Because this was the only use of their second equation, there is a possibly unjustified implication that the domed curve of the gadoids was a special case due to cannibalism.

Three mechanisms have been put forward to account for density-dependent mortality in the egg or larval stages: the aggregation of predators or cannibals, the lack of food during a critical stage, and the rate of growth during a critical period. Because recruitment is variable, from a factor of two or three to one or two orders of magnitude, the three forms of curve cannot be usually distinguished statistically.

The Trend of Density Dependence with Fecundity

Cushing (1971) made a study of density dependence in a wide variety of stocks. An index of density dependence, b, was used in $R = kP^b$. The equation does not really describe the stock/recruitment relation, but the index is related to survival, $R/P = kP^{b-1}$ (as John Gulland pointed out to me). The stocks examined included Pacific salmon, Atlantic and Pacific herring, the Californian sardine, flatfish, and gadoids; in each a fair number of observations were available. Some stocks were more heavily exploited than others, but under exploitation the index of density dependence will be underestimated. Fig. 2 shows the relation between the index of density dependence and the cube root of fecundity; in other words density dependence appears to be a function of the distance apart of the eggs or larvae in the sea. If this regression is true, there is a progression in fecundity from herring and salmon with lightly convex curves to flatfish with a flat-topped curve and gadoids with a pronounced dome, as might be illustrated in Fig. 1. If true, the most important consequence is that the gadoids have a greater capacity for stabilization than the clupeids, can stand a greater degree of environmental pressure, and can be exploited more heavily.

Because doubt can be cast on the nature of the index of density dependence, the data were reworked in Cushing and Harris (1973) using a different method. Equation (1) was used, which we called Ricker's initial equation; it could equally have been named Beverton and Holt's second equation, because in neither were the developmental ideas pursued. The curves were fitted by least squares, i.e. to minimize $\Sigma[R-AP(\exp -BP)]^2$. From the standard deviation of residuals, the standard errors of A, B, and R (at any P) were calculated; then the 95% confidence limits to the curve were calculated. Figure 3 shows curves with confidence limits fitted for four stocks and also the confidence limits to the maxima. It will be seen that the curves and the maxima can be well defined.

The index of density dependence corresponds to $-BP$ in equation (1) where P is the mean stock. For a number of stocks (for which the variability of data is relatively low) the two quantities were highly correlated across a range of fecundities. Hence, the trend suggested in Fig. 2 was supported by a more critical examination of the evidence. There is thus a real difference between the primitive clupeids and the more highly evolved gadoids in that the latter can endure greater environmental variability. The fishery on the Arcto-Norwegian cod in the Vestfjord in northern Norway has survived climatic change since the twelfth century, but that for the Norwegian herring has suffered periodic failures when the climate has deteriorated. The greater fecundity of the Arcto-Norwegian cod ensures a greater capacity for stabilization.

For our present purpose there is another conclusion from the trend shown in Fig. 2. It is that the dome-shaped curve that appears to be characteristic of the gadoids is not a special case, but is part of a more general phenomenon. Then, if cannibalism is to be cited as a cause of

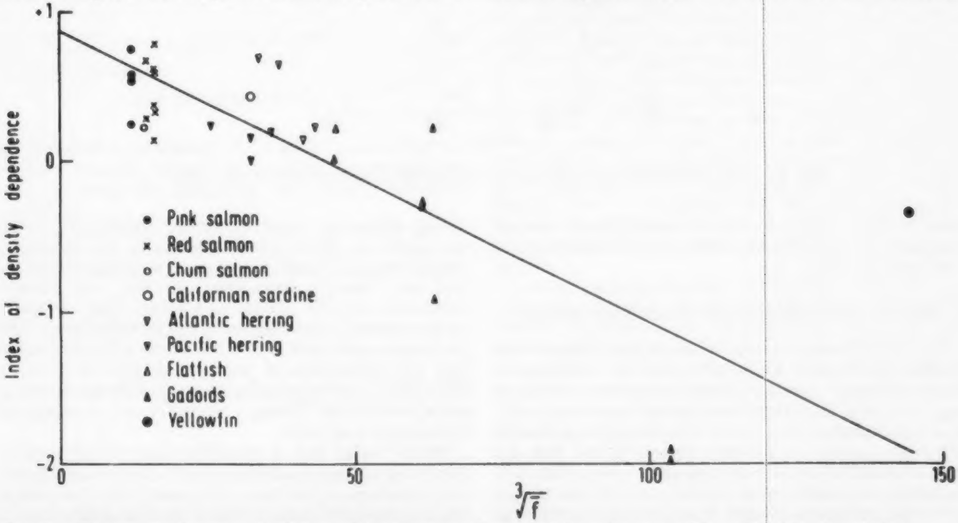

FIG. 2. The relation between the index of density-dependence and the cube root of fecundity (Cushing 1971).

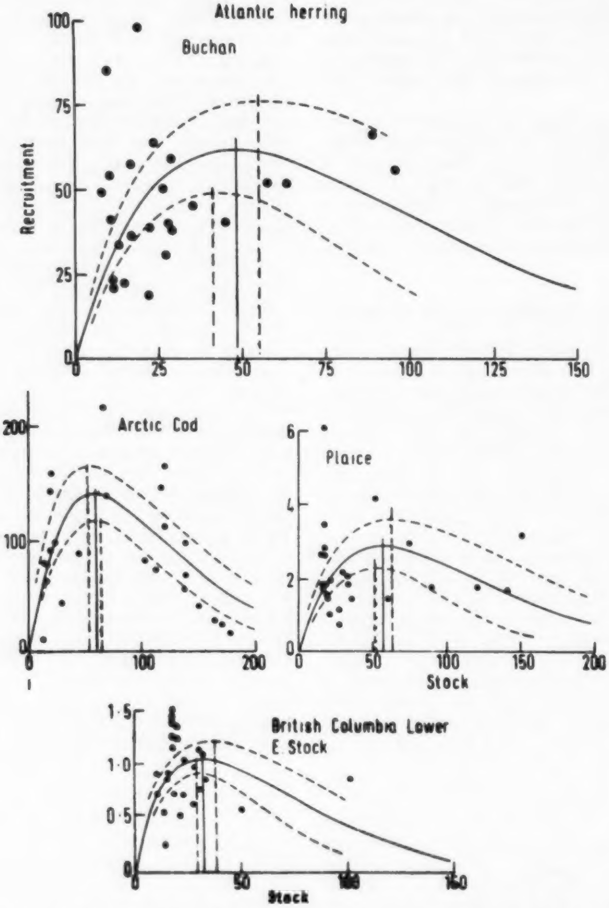

FIG. 3. Stock and recruitment curves for four stocks (Cushing and Harris 1973).

density dependence, it should equally have general application to herring and flatfish as well as gadoids and the Pacific salmon.

Density Dependence and Stock Dependence

Recently, Harris (in press) has reexamined the equation relating recruitment to parent stock. He distinguishes stock-dependent mortality (from the total number of eggs spawned) from density-dependent mortality, which is a function of numbers at any time during the immature life cycle. Ricker's equations express effects that are stock dependent, because the aggregation of predators or cannibals is explicitly related to the initial number of eggs or larvae, which are effective from generation to generation. The first equation of Beverton and Holt expresses density-dependent mortality during juvenile life within one generation. Both forms of mortality are, of course, dependent upon numbers and so, in more general usage, both are "density dependent." Further, any density-dependent mortality (in Harris's usage) must obviously be determined to some degree by the initial numbers. The distinction really lies in the two forms of explanation: first, the aggregation of predators implicit in Ricker's formulation; and second, the survival of larvae according to food availability during a critical period, as suggested by Beverton and Holt.

Harris shows that a mortality that is only density dependent and not stock dependent generates an asymptotic recruitment in stock. The curve for the Arcto-Norwegian cod is characteristic of the four gadoid stocks studied by Cushing and Harris and the gadoid dome is well established. Therefore, Beverton and Holt's first equation does not describe the dependence of recruitment upon the gadoid stock. If the trend of density dependence on fecundity shown in Fig. 2 is true, the gadoid dome is not a special case. Not only should we reject Beverton and Holt's first equation, but we should realize that density-dependent mortality within larval life is an insufficient explanation of the dependence of recruitment on parent stock.

The gadoid dome is explicable in Ricker's equation and the trend in Fig. 2 could be accounted for if differences in stock were correlated with differences in fecundity. However, the trend is dependent upon the cube root of the fecundity, which might be related to the distance between eggs or larvae in the water. Such a trend would require that, for constant stocks in eggs, numbers of fish would vary inversely with fecundity, but, in fact, if big fish are less densely distributed than small fish, they need not be less numerous. Ricker's equation may be applied quite properly to the Pacific salmon, but perhaps it should be limited to that stock. Intuitively, I think that control should be retained within the stock and should not depend on independent predators, just as I believe that control by cannibalism is faintly blasphemous, imputing design failure to omnipotence.

Beverton and Holt's second equation, which finally was identical with equation (1), assumes a mechanism within the stock, the time to grow through a critical period. It is a stock-dependent mortality in which the growth is inversely dependent upon stock at a very early stage in the life history. The distinction between stock-dependent and density effects is clear if the time to grow through a critical period is a long time in terms of larval life. Harris then investigated the relation between stock and the critical time period, t_c. He showed that, for small lengths, the differentiation of t_c with respect to L_∞ equalled $(-L_{t_c}/KL_\infty^2)$, and that on integration

$$t_c = L_{t_c}/KL_\infty. \quad \therefore t_c \alpha\, 1/L \,\alpha\, 1/W^{\frac{1}{3}}. \quad \therefore t_c \alpha\, N_0^{\frac{1}{3}}$$

where N_0 is stock, so:

$$R = AP\,(\exp - BP^{\frac{1}{3}}). \tag{4}$$

This equation is very nearly of the same form as equation (1), but it reasserts the importance of the distance between eggs or larvae in generating the density-dependent processes.

Harris' next step was to ask whether mortality can be both stock dependent (on N_0) and density dependent (on N_t). Differentiating recruitment with respect to stock:

$$\frac{dR}{dN_0} = \frac{RM_r}{N_0M_0} + RM_r(t_r - t_0)\; N_0 \cdot \frac{d}{dN_0}\left(\frac{1}{f(N_0)}\right) \tag{5}$$

where M_0 is the initial mortality at time t_0 and M_r is the mortality at time t_r. The first term expresses the density-dependent processes only and can only generate a recruitment that is asymptotic in stock. Part of the second term was differentiated:

$$f(N_0)\frac{d}{dN_0}\,\frac{1}{f(N_0)} = \frac{f(N_0)}{(f(N_0))^2}\,\frac{d(f(N_0))}{dN_0} = -\frac{1}{f(N_0)}\,\frac{d(f(N_0))}{dN_0}. \tag{6}$$

Harris showed that, if mortality were a product of N_t and an increasing function of N_0, dR/dN_0 might reach zero at $N < \infty$. Thus, if mortality were a function of density alone, recruitment would increase to an asymptote; if it is a function of stock and density, a dome is possible. Summarizing, Ricker's equation relies on stock-dependent mortality, Beverton and Holt's first equation relies on density-dependent mortality, and their second equation depends on stock-dependent mortality; however, an extended critical period would include both forms of mortality. In other words, the relation depends upon the initial numbers and upon the subsequent modification of numbers as the little fish grow up. Such a conclusion resembles Gulland's (1965) suggestion that there might be an initial coarse control of recruitment followed by a fine control.

Beverton and Holt (1957) suggested that the natural mortality of a marine fish population was perhaps density dependent up to and throughout adult life, but that for practical purposes it could be taken as constant with age in a yield-per-recruit model. However, such a constant mortality with age is impossible because the population cannot be terminated in age and this is a point that becomes important in a multiage stock and recruitment study; indeed, the virgin stock is inaccessible in quantity under such conditions. Further, there must be a senility function, like the Gompertz Law, as Beverton (1963) pointed out.

The age structure of the population must be such that the population can be replaced as the cohorts pass through. Replacement must be achieved before senescence starts, if senescence is a property of individuals. It will be suggested that natural mortality is a density-dependent function of age from an initial number generated by *n* gonads to two at a critical age when senescence starts; *n* is the number of fecund age-groups in the virgin stock. The critical age is defined as that at which the specific growth rates and mortality rates are equal. The trend of such mortality with age secures replacement on average and if senescence is determined physiologically, population fecundity must decline after the critical age in the virgin stock. Given this structure, it is possible to construct a yield curve as will be described in the following section.

Ricker (1945) has defined a critical length in a population as that at which the specific growth rates and natural mortality rates are equal; there is also a critical age. Let $G = ln(W_2/W_1)$, where W_1 and W_2 are weights in successive years; let $M^* = ln(N_2/N_1)$, where N_1 and N_2 are numbers in successive years in a density-dependent function of age, as described above. $(G-M^*)$ declines to a critical age where $(G-M^*) = 0$, and at greater ages it is less than zero. In the unexploited stock the age distribution of fecundity (or biomass) reaches a maximum at the critical age. No increment can be expected at a greater age and senescence might be expected then. For the southern North Sea plaice $(G-M^*) = 0$ at the age of 16 (see below), and by then the diameter of white muscle fibers is reduced by 50% (Dr M. Greer-Walker personal communication) so that the capacity of the fish to attack and escape predation is reduced. If senescence is determined physiologically from the critical age onwards, then the total fecundity of the virgin stock is determined by that age.

Let us suppose that natural mortality is a density-dependent function of age between hatching and the critical age. Most fish must die by being eaten. A simple formulation of predation suggests that it comprises the time to handle and eat and time to search, of which the latter is the most important. It is obviously density dependent. Fish grow through a succession of predatory fields and, as growth is a function of age, natural mortality may be considered a density-dependent function of age. It can be shown (Cushing, in press) that:

$$N_T = N_0/(1+M_0T) \tag{7}$$

where: N_0 is the initial number generated by *n* gonads, the number of spawning age-groups; M_0 is the initial mortality; $N_T = 2$; and T is the critical age. At time $t<T$:

$$N_t = N_0(1+M_0t);\ M_0 = (N_0-N_t)/N_tt$$

If the initial number is large and $T>1$, M^* is determined by age and it is the same value at a given age. Cod, herring, and sprat may have the same specific mortality rates at a given age, but their adult mortalities differ considerably because they mature at different ages and survive to different ages.

Stock dependence is given in the initial number and density dependence from the extension of the initial mortality to the critical age. However, it must represent an average condition because the variability of recruitment is not taken into account. Another important point is that it is assumed that mortality is primarily density dependent. Although the variability of recruitment in a stock/recruitment curve is generated more by density-independent than by density-dependent factors, here it is assumed that any density-independent change is subsequently modulated in a density-dependent manner. It has been believed that density-independent mortality is of greater magnitude than the density-dependent component because the variability of recruitment is high as compared with that of stock. However, the same effect can be achieved by the mechanism proposed above.

Hempel (1958) failed to find any trace of density-dependent growth in the southern North Sea plaice; recently I have detected no density dependence in the data from 1929 to 1970. Figure 4 shows the trend in (G–M*) and the critical age is 16. The loss rates of the larvae are known: 80%/month or 99.2%/3 months (Harding and Talbot, in press).

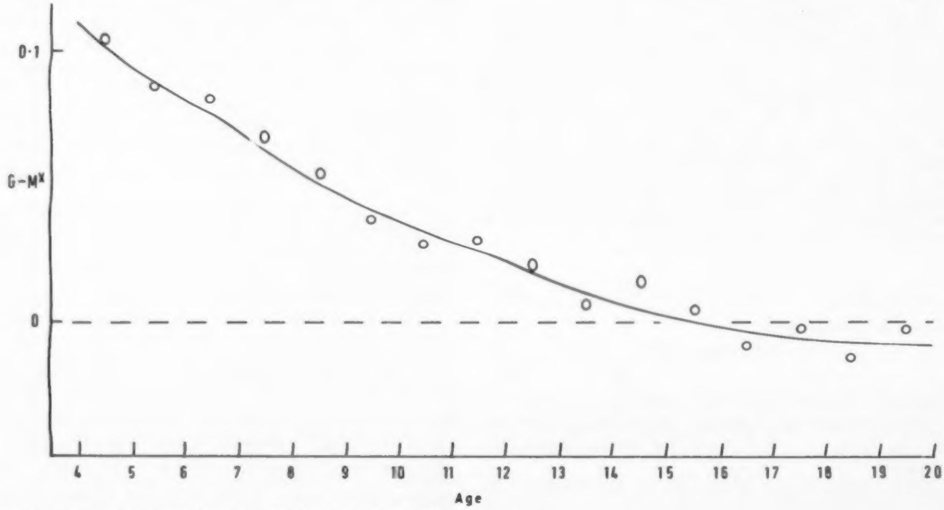

FIG. 4. The critical age in plaice (where $G - M^* = 0$).

$$N_{30}/N_0 = 0.2 = 1/(1+30M_0);\ \therefore M_0 = 0.133$$

Then:

$$M_0 = (N_0-2e^{-F})/(2e^{-F-}\times 13)$$

$$N_0 = 1026.5.$$

N_t was calculated to the critical age; the mortality rates of 0-group fish at 40%/month in June or July and 10–20%/month during the following winter are marked in on Fig. 5. The adult natural mortality is taken from the mortality of the transwartime year-classes (Beverton and Holt 1957) from the ages of 5, 6, or 7 before the war to 13, 14, or 15 after it. Estimated in this way, $M = 0.1$, although Beverton (1964) later suggested that $M♀ = 0.08$ and $M♂ = 0.12$. With a larval mortality rate of 80%/month, the average adult mortality rate calculated from the ages of 5–15 was 0.112. Thus, from hatching to the

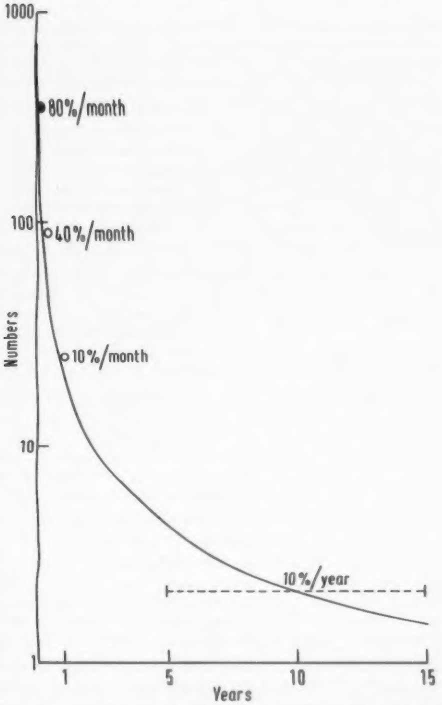

FIG. 5. The trend of natural mortality with age in the plaice.

critical age the trend of mortality with age can be fairly well simulated, if the larval mortality rate is known (Fig. 5). Because the specific mortality rates turn out to be the same at each adult age, the trend in adult natural mortality can be specified without knowing the larval mortality rate.

Cushing (in press) has attempted to estimate the rate of senescence in the southern North Sea plaice stock. Beverton (1963) expressed the Gompertz Law in the following way:

$$N_t = N_0 \exp -[\exp(m_0 + m_1 t)] \qquad (8)$$

where m_0 is the natural mortality at the critical age and m_1 is the rate at which senescent mortality increases with age. The method of fitting the equation is given in the above paper. Since 1963 otoliths of the plaice population of the southern North Sea have been burned and, for some samples, age determinations have been made up to the age of 35. The samples were taken from the year-classes 1933–50.

The samples were expressed in a catch curve for the years 1964–69. Such a procedure is subject to bias if mortality changes with time. Since 1947 the total mortality has probably declined and so the catch curve underestimates it. However, during World War II the stock suffered no fishing and the combination of the two factors generates a concave catch curve. The observations in Fig. 6 from age 16 to 30 are grouped in a convex curve, which might well be described as a senescent function.

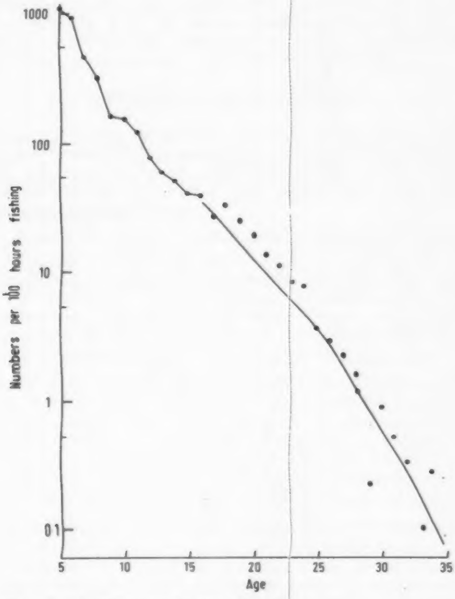

FIG. 6. Senescence in the plaice.

Figure 6 shows the trend in numbers/100 hr fishing by age, averaged for the years 1963–70. The trend from age 16 to 32 was fitted by equation (8). From age 5 to 15 mortality decreased with age, as might be expected if natural mortality were decreasing with age and fishing mortality remained constant. After the age of 16 mortality increased with age, as would be expected if the fish were becoming senescent. Mortality decreases to the critical age and subsequently increases, which lends support to the idea that senescence may start then. Fishing mortality could decrease as fish got bigger and then increase as fish became senescent, but such a hypothesis requires that senescence be established in a different way. If senescent fecundity were to play a part in stabilizing the virgin stock it might take up the variability of recruitment. If recruitment were high, the stock would be more than replaced and the excess would be taken in the density-dependent processes of the following generation. If recruitment were low, stock would not be replaced by the critical age but the senescent fecundity might do so. If this were true the ratio of senescent fecundity to total fecundity would correspond to the coefficient of variation of recruitment.

A Yield Curve Incorporating the Dependence of Recruitment on Parent Stock

When Ricker faced the problem of a multiage stock, he wrote (1958) that recruitment should be expressed as the sum throughout the cohort less the natural mortality,

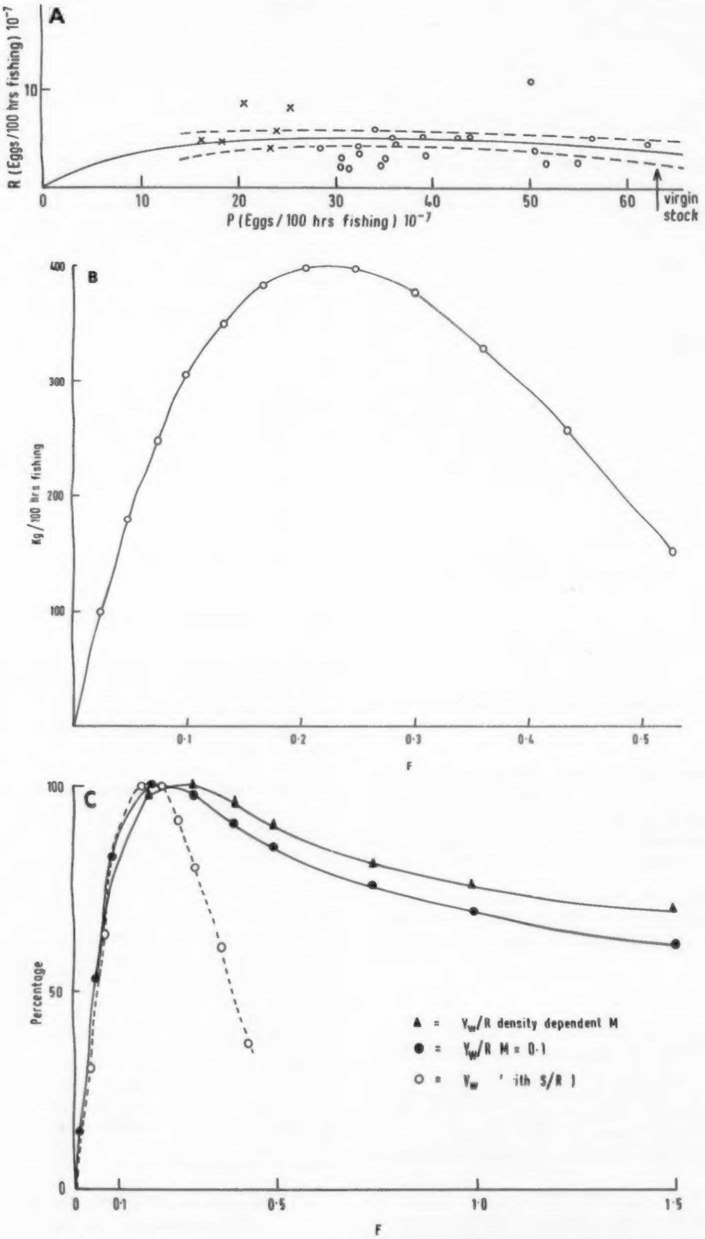

FIG. 7. A, Stock/recruitment curve for the southern North Sea plaice, 1929–70; B, Yield curve for the southern North Sea plaice; C, Yield curve and two yield-per-recruit curves: 1, with M = 0.1; 2, M density-dependent.

which reduces the problem to that of the single-aged stock. But this requires that natural mortality be estimated independently; any of the constant mortality approximations must lead to an incorrect estimate of the virgin stock and hence a slight bias in the yield curve (in a part of the curve however where bias might not matter much). It is possible that replacement in a multiage stock should be regarded a little differently. Any one recruitment is usually a rather small fraction of the unexploited stock. In the year of recruitment the gain in numbers by recruitment is balanced by the loss in deaths. The gains and losses are averaged throughout the lifespan, which represents replacement but is being modified in time continuously. Although stock must be replaced by recruitment, the concept of a replacement stock, in Ricker's sense, is perhaps not needed in a multiage stock.

It would be idle to suppose that the values of specific annual mortality at successive ages, as calculated from equation (7), represent more than average values for any stock and there may be variations between species due to a variety of conditions. However, in the plaice at least, there is some evidence that equation (7) represents the natural mortality across a number of age-groups, 0–16. Further, there is some reason to suppose that senescent mortality has been represented fairly well. Given P, R, F, and the trend of natural mortality with age, the stock in age can be reconstituted and compared with the initial value from the stock/recruitment curve (Fig. 7a) itself, appropriate to the value of recruitment used. The number of fish at 4 years of age is given by $R/(W_t \cdot \o)$ where R is in eggs/100 hr fishing, W_t is the mean weight at age of 4-year-old female plaice, and $\o$ is the fecundity constant (143.92 eggs/g in the plaice; Simpson 1957). N_t is then calculated for each age from $N_{t+1} = N_t e^{-(F+M^*)t}$ etc. The stock densities in numbers at each age are raised by the weight at age to give biomass as kg/100 hr fishing at each age. They are summed from ages 4 to 21 to give P for that value of F. The reconstituted value of stock only corresponds with the initial value (from the stock/recruitment curve corresponding to R) if F is correctly estimated. At the present time most values of F are obtained from Z–M, with M constant with age; the reconstituted value of stock can only rarely equal the initial one.

Let $N_1 = N_0 e^{-(F+M_1)}$

$$dN_1/dF = -N_0 e^{-(F+M_1)} = -N_1$$

$$N_2 = N_1 e^{-(F+M_2)}$$

$$dN_2/dF = -N_1 e^{-(F+M_2)} - N_1 e^{-(F+M_2)} = -2N_2$$

$$N_3 = N_2 e^{-(F+M_3)}$$

$$dN_3/dF = -N_2 e^{-(F+M_3)} - 2N_2 e^{-(F+M_3)}$$

$$= -3N_2 e^{-(F+M_3)} = -3N_3.$$

The biomasses at age were multiplied by 0, 1, 2, . . ., 18 from ages 4 to 21, summed, and raised by the fecundity coefficient to give dP/dF. Then:

$$F_1 = F_0 - \frac{(P_0 - P_1)}{dP/dF}$$

(this use of Newton's method was carried out for me by my colleague J. G. K. Harris). By iteration a true value of F for each stock value was obtained. The catch in numbers from one age to the next was taken from:

$$(F/Z)(N_0 - N_1) \text{ or } (qf/Z)(N_0 - N_1)$$

where q is the catchability coefficient and f is fishing intensity, and Y_n was raised by the average weight during the year to give catch in weight. In this way a yield curve in numbers or in weight was constructed from the stock/recruitment curve.

Figure 7A shows the stock and recruitment curve for the southern North Sea plaice based on catches/100 hr fishing in kilograms by age-groups between 1929 and 1970. The value of the virgin stock is shown and it was calculated using the above method, when F = 0. Figure 7B shows the yield curve in weight calculated in this way, with a maximum at F = 0.2. Figure 7B is expressed in stock density on fishing mortality. It is not strictly a yield curve and further it is apparently confused with the familiar dependence of stock density on effort. A catchability coefficient might have been used as suggested above or stock numbers might have been obtained by virtual population analyses. Figure 7C shows the same curve and the yield-per-recruit curve in values relative to the maximum. The yield-per-recruit curve was calculated first with M = 0.1 and second with the density-dependent values calculated from equation (7). Thus, for the plaice, the maximum of the yield curve differs little from the yield-per-recruit curve, as might be expected; however, as indicated below, the right hand limb is too steep. Nevertheless, the maximum remains sharp and should not be exceeded.

Figure 8B shows yield curves calculatedin the same way for the Arcto-Norwegian cod. Because the variance of recruitment in this stock is not very different from that of the plaice, the same senescence function has been used; as noted above, if these values are incorrect, the yield curve becomes slightly biased at very low values of fishing mortality, but the position of the maximum is not displaced. No trend in time in weight for age for this stock of cod is known and so the scale in F is probably unbiased. The scale in F differs from that in Garrod's model (this meeting) because he has used a natural mortality of 0.3 at all ages and the difference in the maxima is not very great.

There are three possible sources of bias. Two arise if the model is compared with one that uses a constant mortality in age. First, from the age of maturation to the critical age the mean age in M* is less than the median age, so F* > F by a constant but small quantity, so the bias decreases with increasing F. Second, because M* decreases with age, the exploitation ratio (F*/Z) increases with age and catches from older age-groups comprise a greater part of the total; the bias is low and increases slightly with F*. The third bias occurs if a growth change has occurred during the period to which the stock/recruitment curve applies, e.g. in the plaice the length at age has apparently increased. Because the increase in length is not yet properly understood, the reconstituted biomass is less than it should be and F* is underestimated. Hence Fig. 7B and C have only pictorial value because the F* scale is low. However, the maximum is properly estimated and the right hand limb is probably much too

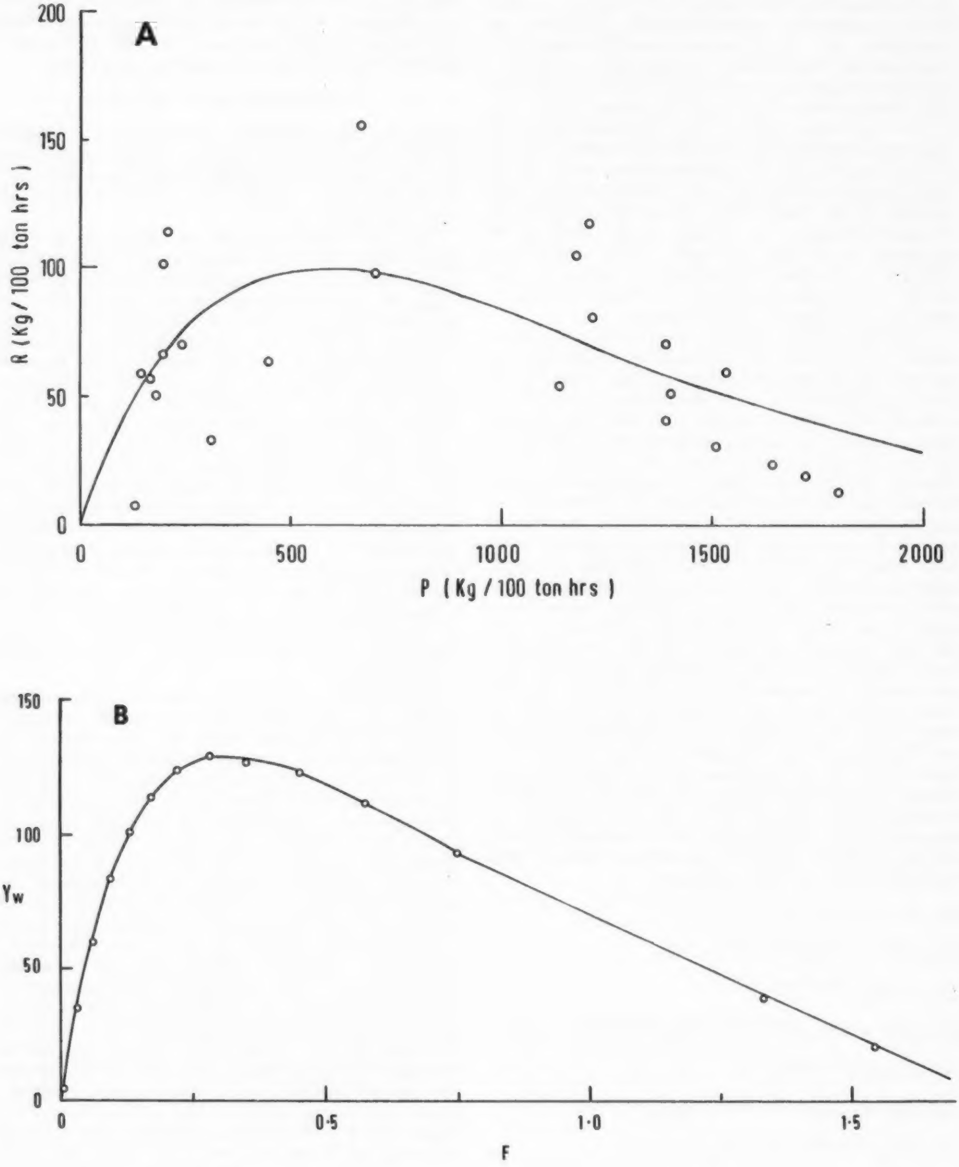

FIG. 8. The Arcto-Norwegian cod: A, Stock recruitment curve; B, Yield curve.

steep. The flat curve of recruitment on parent stock should generate a maximum at about the same place as that of the yield-per-recruit curve, so the management judgement remains the same. However, perhaps a manager would be less willing to exceed the maximum on the yield curve than on the yield-per-recruit curve. With a dome-shaped curve of recruitment on parent stock the maximum of the yield curve is expected to lie to the left of the maximum of the yield-per-recruit curve.

There are three important characteristics of the yield curve calculated in this way: at rates of exploitation less than Ricker's limiting value, the condition of population stability if fulfilled; the curve could be fitted to total catch data in much the same way as is the Schaefer curve; estimates of fishing mortality are free from bias within the limits imposed by the estimate of natural mortality and the stock/recruitment curve. The main disadvantage to the method is that it includes the variability inherent in the stock/recruitment curve; although the variability of recruitment can be very high, the variability of the curve itself is often not too great (Fig. 3).

Conclusion

Studies of the stock/recruitment relation are restricted by our knowledge of the population dynamics of larval and juvenile fishes. In particular, information is needed on the nature of the link between density-dependent growth and mortality and their relation to the availability of food. Jones (1973) has developed a model in which larvae die if they fail to catch a specified number of food organisms, and a density-dependent mortality was generated. Cushing and Harris (1973) described a similar model: as larval plaice grow, they swim more quickly and evade capture from a particular predator. Variations in numbers of larvae generate a density-dependent mortality, governed by the availability of food, as Ricker and Foerster (1948) and Beverton and Holt (1957) have suggested. The problem is to describe the course of density dependence in time in response to food availability. It is probably the fine control of recruitment, which Gulland (1965) referred to. The two models are specific ones that describe the lives of fish larvae, but they could be generalized to most of the life cycle and this provides the main justification for supposing that natural mortality throughout adult life is density dependent.

For a long time the belief that recruitment is independent of parent stock throughout the fishable range of stock has been dogmatic. It originated in the study of plaice and halibut and for them might still be true. But it is not true for clupeid or gadoid stocks in general. From a management point of view, the dogma should be abandoned. Perhaps the same conclusion might be reached for some stocks on the basis of a proper study of stock and recruitment. It would be a much safer position than the merely dogmatic one. Much more important, however, the dangers to many clupeid and gadoid stocks would become obvious.

Very recently, the recruitment to the Peruvian anchoveta fishery has appeared to fail. Because these animals do not grow very much during their adult lives and because they are not very fecund anyway, the capacity of the stock to stabilize itself cannot be very great. It is unlikely that the stock/recruitment curve can yet be established as reliably as those shown, for example, in Fig. 3. However, the fishing mortality is high and the exploitation rate may be about 0.5. At such rates, the stock of Californian sardines collapsed and the simplest hypothesis is that the collapse was the consequence of the high rate of exploitation. The same form of simple hypothesis is enough to account for the recent collapse of the Norwegian herring and the earlier failure of the Downs stock of herring, both under the pressure of fishing. By far the most important management step is to recognize the possibility that the failure of recruitment might well have been a consequence of heavy fishing.

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Management of Multiple Resources

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From the point of view of the exploiting industry, fisheries can be classified according to the breadth of its resource base, varying from single-species fisheries to integrated multiple-resource fisheries.

All resources exhibit short-term fluctuations, which in the multiple-resource fishery necessarily lead to differential rates of exploitation of the component resources.

The differential rates of exploitation in the components of a multiple resource, even by aimed activity of the same vessels, imply nonequilibrium conditions in the individual stocks. This contrasts with the basic objective of conventional stock assessments to establish yield under equilibrium conditions.

A technique of investigating and comparing yield from resources in equilibrium or nonequilibrium is illustrated with reference to North Atlantic cod, the "equilibrium" fishery being one in which the distribution of fishing is independent of stock density, whereas the nonequilibrium characteristics of a multiple-resource base are associated with a distribution of fishing mortality weighted by the density of the component resources.

Provided fishing mortality varies about an appropriate mean level, there is no marked difference in yield under equilibrium or nonequilibrium conditions. Fisheries are robust systems which can tolerate wide between-year variations in fishing mortality provided it fluctuates around an appropriate mean level. This implies that there is no advantage in trying to manage a fishery by a precise control of fishing mortality.

Under certain circumstances, determined by the variability of the particular resource complex, a density-dependent regime of exploitation may be a more efficient method of exploitation of a given array of resources. This has the additional advantages of reducing the year-to-year variation in yield to the total fishery and of reducing the risk of overexploitation in cases where catchability can be expected to be inversely proportional to stock abundance.

Du point de vue industriel, les pêcheries peuvent être classées selon l'importance de la gamme de ressources qu'elles exploitent, que leurs opérations portent sur une seule espèce ou sur plusieurs.

Toutes les ressources accusent des fluctuations à court terme qui, dans le cas d'une pêche portant sur plusieurs espèces, se traduisent nécessairement par des degrés divers d'exploitation des divers éléments composant la ressource.

L'exploitation à des degrés différents des éléments composant une ressource multiple, moyennant les opérations des mêmes navires, infère un déséquilibre dans les conditions de chacun des stocks, ce qui va à l'encontre de l'objectif fondamental visé par les évaluations classiques des stocks qui est de déterminer le rendement dans des conditions équilibrées.

Des recherches et des comparaisons sur les rendements des ressources en conditions équilibrées ou non équilibrées peuvent se faire selon la méthode appliquée à la morue de l'Atlantique Nord, la pêche en "conditions équilibrées" étant celle dans laquelle les opérations se répartissent indépendamment de la densité du stock, l'exploitation en "conditions non équilibrées" d'une ressource multiple étant associée à une répartition de la mortalité par pêche pondérée par la densité des divers éléments constituant la ressource.

On constate que, sous réserve que le taux de mortalité par pêche varie autour d'une moyenne appropriées, il n'y a aucune différence marquée dans le rendement en conditions équilibrées ou en conditions non équilibrées. Les pêcheries sont des systèmes robustes capables de supporter de fortes fluctuations interannuelles dans le taux de mortalité par pêche, à condition que celui-ci varie aux alentours d'un niveau moyen approprié. Il apparaît donc que rien ne sert de tenter d'aménager une pêcherie moyennant un contrôle précis de la mortalité par pêche.

Dans certaines circonstances, régies par le caractère variable de la ressource en fonction de la densité doit constituer un moyen plus efficace pour exploiter un ensemble donné de ressources. Cela offre l'avantage supplémentaire d'atténuer la fluctuation d'année en année du rendement par rapport à la pêcherie totale et de réduire le risque d'une surexploitation là où la fréquence des captures est censée être inversement proportionnelle à l'abondance des stocks.

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Desde el punto de vista de la explotación, las pesquerías pueden clasificarse, según la variedad de los recursos que explotan, en las de una única especie o las integradas que explotan recursos múltiples.

Todos los recursos muestran fluctuaciones a corto plazo que, en las pesquerías de recursos múltiples, hacen necesariamente que los índices de explotación de los diversos recursos que la integran sean diferentes.

La diferencia en el índice de explotación de los diversos recursos que componen una pesquería de recursos múltiples, aún cuando se deba a la orientación de la actividad de unas mismas embarcaciones, implica una situación de no equilibrio en las diversas poblaciones, que contrasta con los objetivos fundamentales de las evaluaciones convencionales de las poblaciones: determinar el rendimiento en condiciones de equilibrio.

Se presenta una técnica para estudiar y comparar el rendimiento de los recursos en equilibrio y en no equilibrio, tomando como ejemplo el bacalao del Atlántico Norte; una pesquería en equilibrio es aquella en la que la distribución del esfuerzo de pesca es independiente de la densidad de las poblaciones, mientras que la situación de no equilibrio de una pesquería de recursos múltiple está asociada con una distribución de la mortalidad por pesca compensada por la densidad de los recursos que la componen.

Se muestra que a condición de que la mortalidad por pesca varíe en torno a un nivel medio adecuado, no existe ninguna diferencia notable de rendimiento entre una situación de equilibrio y una situación de no equilibrio. Las pesquerías son resistentes, y pueden tolerar amplias variaciones anuales en la mortalidad por pesca, a condición de que fluctúe en torno a un nivel medio adecuado. Por tanto, intentar regular una pesquería establesiendo un control exactísimo de la mortalidad por pesca no tiene ninguna ventaja.

En determinadas circunstancias, motivadas por la variabilidad del complejo de los recursos, un régimen de explotación que tenga en cuenta la densidad puede constituir un método más eficaz de explotación de una serie determinada de recursos, con la ventaja, además, de reducir las variaciones anuales de rendimiento de la pesquería total y de reducir el riesgo de superexplotación en aquellos casos en que se puede esperar que la capturabilidad sea inversamente proporcional a la abundancia de la población.

Historical Development of Fisheries

SCIENTISTS discuss fisheries management in terms of the effect of exploitation on the resource, classifying fisheries according to the species or the kind of gear used, etc. In this paper I propose to reverse this viewpoint, to examine the effect of the available resource base on the fishery that exploits it. For this purpose fisheries may be classified in three groups: single-species fisheries, single-species fisheries successional in time and area, and integrated fisheries.

SINGLE-SPECIES FISHERIES

Almost inevitably all fisheries depend on a single species at their inception, because one is predominant in value and generates the incentive for development: without it the fishery would not exist. This phase is frequently difficult to discern, or is lost in history, especially in coastal fisheries, but some classic examples of marine single-species fisheries are: Hokkaido/Sakhalin herring; British Columbia herring; California sardine; Indian oil sardine; Indian mackerel; Peruvian anchoveta; Black Sea anchovy; Pribilof Island fur seals; Pacific halibut.

Fisheries with such a restricted resource base are in fact rare, and it is true that some of the above-named do contain a by-catch of other species. But within those listed there is a discernible trend in the evolution of the single-species fishery as a type. For some (e.g. Indian oil sardine, Indian mackerel), the mode of exploitation is not yet fully industrialized, or they are of comparatively recent origin in their developed form (Black Sea anchovy, Peruvian anchoveta). Of those that became fully developed years ago, many have virtually disappeared through recruit failure (Hokkaido/Sakhalin herring, California sardine), or have been subject to stringent regulation in an effort to restore failing recruitment (British Columbia herring, Pribilof fur seals).

SUCCESSIONAL FISHERIES

The blue whale "fishery," its collapse, and the consequent extension of activity to other species is the best known transition from a single-species to a successional fishery. At the present time the collapse of the purse-seine fishery for Atlanto-Scandian herring represents the failure of a single-species fishery to the Icelanders, and the onset of successional fishing for Norway whose fleet was redeployed first to capelin and later to mackerel. This second resource was rapidly depleted to a level requiring management action to limit exploitation, and since the capelin resource is characteristically highly variable it is not expected to sustain the fishery indefinitely, so the yield potential of blue whiting is being investigated as another possible objective. The ultimate failure of recruitment, which seems to be commoner in single-species fisheries, has been variously ascribed to environmental causes or to exploitation, though it is only for the fur seals and whales, with their low reproductive rate, that the evidence for the effect of exploitation is really convincing. Where the single species has collapsed the fishery has, wherever possible, moved on to a second resource, becoming a successional fishery in time.

An analogous development is being shown by the Netherlands beam trawl fishery for North Sea soles. The reintroduction of beam trawling with the use of added chain to dig fish from their protected position just under the surface of the seabed has rapidly increased the exploitation of the North Sea sole and, although this primary resource has not collapsed, local depletion has forced the fleet to seek out sole resources in other areas to sustain its activity on a year-round basis.

The differences between fisheries which are, by this classification, successional in time or area is really a matter of degree. Some fisheries become so specialized, or the collapse of a resource is so rapid, that the change from dependence on one resource to dependence on another occurs quickly. More often, depletion of one resource increases the relative economic attraction of another and the area of exploitation becomes extended. The development of trawling in the North Sea in the late 1800s was a case in point, and the development of the North Sea sole fishery could equally be considered here as a more recent example of the process. The expansion of the oceanic tuna fisheries, the Alaska pollock fishery, and the North Atlantic cod fisheries are analogous examples. This expansion of the area or species exploited certainly reflects the fundamental need of an industry to develop, but it also reflects the need to spread the load of fishing capacity over a wider resource base.

INTEGRATED FISHERIES

The successional fisheries referred to above themselves merge into integrated fisheries. The depleted resource left behind in the search for new pastures will gradually recover; as it does so it will exhibit seasonal peaks in abundance which will reattract fishing for a time. Or in many instances the seasonality of fisheries is such that fish from different stocks can be caught only at particular times of the year, leading to a fishery integrated over several resources. The North Sea herring fishery of years gone by developed in this way while the drift net was the major gear in use: the seasonally integrated fishery collapsed with the development of gears which permitted exploitation of most stocks on a year-round basis. Coastal fisheries exploiting a wide variety of species with different gears and according to their seasonality are the most widespread integrated fisheries. By definition, they exploit a restricted area, but they have a counterpart in the mobile fleets exploiting a wide variety of species over a wide area as exemplified by the high-seas fisheries of the USSR and Japan.

It is clear from this résumé of well-known examples that the persistently successful fisheries are those with the widest resource base, achieved by the number of resources and operational flexibility. A fishery on a limited resource base is associated with variable catches, and often highly specialized fishing techniques developed to take even further advantage of those behavioral characteristics of the resource, e.g. shoaling, which initially made the single-species fishery viable. In the absence of management such specialization finally leaves both the fishery and the resource vulnerable to the lag effects of excessive fishing.

Diversification thus appears to be an important element in the long-term success of a fishing industry, enabling the "load" of exploitation to be widely spread over a number of resources. The remainder of this paper reviews one approach to the study of interaction between fisheries on multiple resources, because even though the exploitation load can be spread, it remains true that this process must ultimately be limited: the resources of the world's oceans are finite and fishing industries cannot grow indefinitely in size, though they may continue to grow in value.

Study of Multiple Resources

The theory of fisheries management has been developed with respect to the biological attributes of individual resources but, as the foregoing remarks have shown, many industries must necessarily depend upon a number of resources. Research upon the interactions between resources themselves, or between several resources and a single source of exploitation, has barely started. Yet it is important not only for its greater realism, but also because the basic assumption of current theory, that the fish/fishery interaction is a random process, is certainly not valid and there is a need to find out to what extent this may modify stock assessments currently presented as a basis for management.

Beverton and Holt (1957), in their comprehensive account of the management of single resources, showed how the yield of multiple resources could be manipulated on an additive basis. Larkin (1963, 1966) has provided solutions to the management of species which compete in the same trophic level or interact between trophic levels, and Paulik et al. (1967) have presented an analytical solution to the exploitation of noninteracting multiple resources that is analogous to the Beverton and Holt approach but with the important extension incorporating stock and recruitment relations which vary between stocks. Dickie (1972) is investigating similar problems from a different point of view, maximizing production by making use of the ecological efficiency at different trophic levels: in effect a vertical integration of resource potential rather than the lateral integration characteristic of most existing fisheries.

Larkin refers to transitional states, but the primary intention of these studies has been to establish how the characteristics of an equilibrium in one resource may be modified by interaction with a second. Riffenburgh (1969) has developed a stochastic model to evaluate the effects of ecological interactions between prey species on the yield to a multi-species fishery with time. He considers nonequilibrium ecological conditions but under specified constant rates of growth, recruitment, and exploitation to the stocks. However, as Riffenburgh points out, one of the most important attributes of all species is that recruitment varies and with it the relative attraction of different resources to the exploiting fishery. In practice then, the amount of fishing devoted to one species will vary. The nonrandom distribution of fish with respect to fishing is enough to enable the fishery to concentrate more on one species than another, even though they may be caught together. In these circumstances, the effective fishing mortality applied to each resource will vary in time and the equilibrium solution can be realized only under rare circumstances. When asking what constant level of fishing mortality will maximize the yield in a multiple resource fishery, we also need to know what level of fishing mortality will be generated on each of them and whether or not their yield under nonequilibrium conditions has any special characteristics which are not obvious from existing unit-stock assessments.

It is a matter of common experience that analytical formulations which will provide solutions to the assessment of more than one stock rapidly become intractable, and for the analysis of nonequilibrium conditions computer modelling techniques have been used to provide realizations of particular circumstances in discrete time. Paulik, Larkin, and Riffenburgh have developed models appropriate to their problems and, more recently, Clayden (1972) has developed a model to examine the interactions between a number of sources of fishing effort exploiting the same range of resources which has been especially useful in describing the evolution of the North Atlantic cod fisheries as a resource complex.

COMPUTER MODEL (DEVELOPED FROM CLAYDEN 1972)

From catch and fishing effort statistics, age census data, and biological investigations, the following population characteristics are determined: (i) the number of fish in the stock, by age-groups, in an initial year; (ii) the number of young fish of specified age recruiting to that stock in subsequent years; (iii) the weight at age; (iv) the availability of each age to the fishing gear; (v) natural mortality; (vi) the seasonal distribution of catchability. These represent the basic biological data matrices.

The amount of fishing in units related to the catchability (vi) is the input for the various sources of fishing in an additional matrix which is applied to the stocks on a monthly basis to generate catch and survivors in numbers which are then calibrated to catch weight and biomass. The new recruits (ii) are introduced and the age-groups updated at the end of each year. In complex situations, the migration of fish from one stock to another may be simulated by age-group and appropriate month. A similar facility enables fishing effort to migrate from one stock to another according to specified constraints. In its routine for each month, the model scans the relative catches per unit effort in each stock and then allocates the effort from each effort source in proportion to the catch per unit efforts as modified by weighting factors which reflect, for example, the operating distance of each resource from home ports and the speed with which fishing can redeploy from one area to another.

These facilities permit the population parameters determined by analysis to be used in a reconstruction of a fishery. The effect of changes in gear selectivity, control of the amount and distribution of fishing mortality, or the closure of areas and seasons can be investigated by manipulation of the appropriate matrix. Likewise, the model can be used to integrate the effects of one type of fishing on a variety of species, or a variety of fisheries on one species, or a combination of both. The important advantage over unit-stock assessments is the stock density-dependent (i.e. value-dependent) distribution of fishing mortality.

The model still excludes ecological interaction between species but, used in this form, can provide a postmortem on past events, or an insight into what might have happened under alternative management strategies. Its value for prediction in real time depends on foreknowledge or assumptions about future recruitment and trends in matrix can be replaced by a spawning stock/recruitment relation allied with a variable representing the density-independent effects of the environment. Each stock then has a regenerative loop and the effects of various hypotheses linking stock and recruitment can be investigated.

North Atlantic Cod Fisheries

The North Atlantic cod fisheries represent a highly developed, integrated fishery which, by consensus among scientists, is now fully exploited in the sense that no further increase in the long-term yield is expected. The development and present status of the total fishery has recently been described by the ICES/ICNAF Working Group on North Atlantic Cod Stocks (Anon. 1972). This report is reviewed below to illustrate the problems that arise in the management of such a fishery and the contribution that computer modelling techniques can make to their solution.

The North Atlantic contains 15 more or less separate major cod stocks on the continental shelf bordering or within the North Atlantic basin. All are subject to a common fishery from at least 17 countries, though not all vessels involved have full range over all the resources. The size and environmental conditions of the individual stock areas vary considerably and, consequently, so do their biological characteristics, particularly the size of the stock and the growth rate of the fish in them. The fleets exploiting the resources operate at different distances from their home ports and so differ in their size and design and hence potential fishing power. Moreover, some fleets exploit predominantly breeding fish, whereas others take their catch from a wider range of ages.

During the period 1955–70, total catches of cod from this complex have fluctuated around 3 million tons with a peak of nearly 4 million in 1968. The overall yield has remained surprisingly stable, though there have been considerable changes in the pattern of exploitation between component stocks. At the beginning of the 1960s the Northeast Atlantic cod resources were already fully exploited, being in closest proximity to the north European market, but the Northwest Atlantic resources were less heavily exploited. About that time, a decline in catches in the Northeast caused some countries to extend their activities westward, where initially high catches were taken on stocks adjusted to relatively low exploitation at that time. The extended range of operation stimulated the development of vessels with increased duration at sea, and while enough fishing remained in the Northeast to maintain full exploitation there, stocks in the Northwest Atlantic were gradually brought to the same level. Now, in the early 1970s, all the cod stocks are fully exploited by an international fleet composed partly of vessels with limited range operating on single stocks in their own locality and partly of others with unlimited range which are able to fish anywhere in the North Atlantic according to short-term fishing prospects. The outcome has been that the abundance (i.e. catch per unit effort) of all the stocks is tending to the same level, but any stock that offers an improved catch, usually through the appearance of a strong year-class, immediately attracts increased fishing.

Scientific analyses on the unit-stock basis have shown that all these resources are fully exploited and, in fact, a proportion of the existing fishing effort is superfluous to the minimum required to secure the potential harvest. Using the appropriate stock parameters in Clayden's model, the ICES/ICNAF Working Group was able to achieve a fairly good fit to the historic catches from the fisheries (Fig. 1) and demonstrated that they could be restabilized to catch about 95% of the available production, using two-thirds the current level of fishing mortality (Fig. 2), though an abrupt reduction in fishing might not be the most appropriate way of implementing such a regulation. It is believed this would benefit the economic performance of the catching industry so far as cod are concerned.

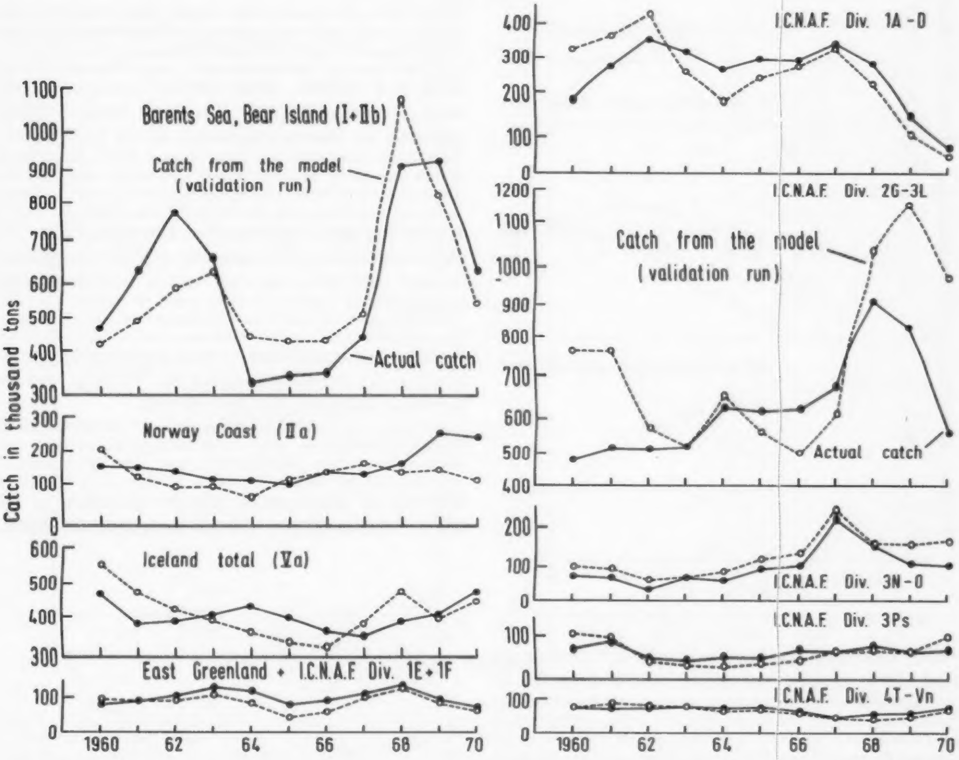

FIG. 1. Comparison of actual catches in North Atlantic cod stocks, 1960–70, with catches predicted by a computer model based on the calculated parameters of each stock (Anon. 1972).

The overall status of these cod stocks is not thought to be critical in any long-term sense, but a biological uncertainty arises from the potentially rapid shifts in the distribution of fishing between the component resources, which means that in individual years stocks may be subject to a level of fishing which would over- or underexploit them. Even though fishing mortality may seem appropriate when averaged over a period of years, intense short-term overexploitation (pulse fishing) can damage a resource, as has been amply demonstrated by the recent history of the Georges Bank haddock stock. Concern for this possibility in respect to cod has influenced management, and the agreement to regulate catches from a number of Northwest Atlantic cod stocks reached at the 1972 Annual Meeting of ICNAF was intended to minimize the interactions between fisheries and hence stocks. From this, it might be inferred that on the whole such interactions are harmful, which has not so far been demonstrated, and this is important because they are generated primarily by natural fluctuations in recruitment and so become a characteristic of all integrated fisheries. The interactions described are usually associated with the flexibility in operation of fishing fleets which may be redeployed from one geographical area to another, resulting in the distinction between the so-called "mobile" and "nonmobile" fleets. In practice, an exactly analogous problem exists where a fleet diverts its activity from one species to another in the same geographical area: in both cases the distribution of fishing mortality is dependent on the relative abundance of the resources.

The effects of instability of fishing mortality on a given resource, or the "density-dependent" distribution of fishing mortality between the components of multiple resources, are a problem central to the management of fisheries because they have a direct bearing on the need, or otherwise, for regulations that will ensure the allocation of fishing mortality down to the level of individual resources within a complex.

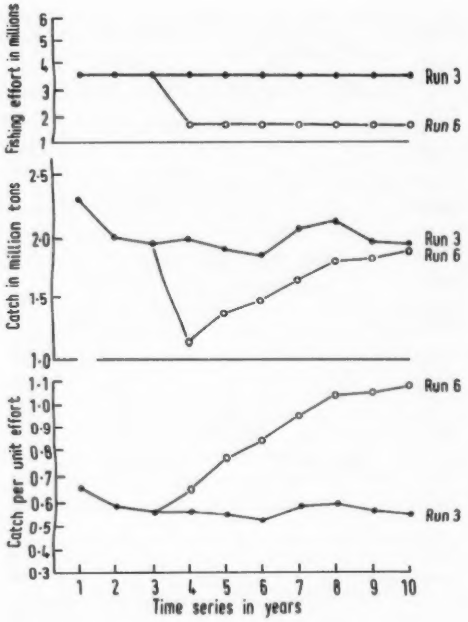

FIG. 2. Changes in catch and catch per unit effort in the total North Atlantic cod fishery as a consequence of management to regulate fishing effort on an Atlantic-wide basis (after Anon. 1972). (a) Fishing effort stabilized at its 1970 level (Run 3); (b) Fishing effort in Year 3 decreased to one-half the 1970 level of fishing effort (Run 6).

Investigation of Yield under Conditions of Density-Dependent Distribution of Fishing Mortality

The outcome of complex stock and fishery interactions depends critically on the characteristics of each set of circumstances. In order to isolate the effects of variable fishing mortality alone, two matrices of up to five identical resources were established, one having biological characteristics based on cod and the other based on sardines. These represent the contrast between a long-lived species with an extended period of growth and a relatively short-lived species with negligible growth after recruitment to the fishery. For each type, yield assessments were established on two hypotheses concerning recruitment: (i) with log-normally distributed density-independent random variations in recruitment; (ii) as (i), with the addition of a density-dependent stock and recruitment function of the form described by Paulik et al. (1967) and Cushing and Harris (1973), and obtained by fitting $R = AEe^{-BE}$ to the available data for Arcto–Norwegian cod and California sardine. A and B are constants and E the egg production of the stock.

These hypotheses represent realistically the extreme possibilities, depending upon one's view of the relation between stock and recruitment. For each hypothesis the expected yield was established under conditions where a specified level of fishing mortality was allocated to each stock in a complex. These identified the conventional *locus of equilibrium yield at constant levels of fishing* mortality, i.e. density-independent fishing patterns, and were contrasted with the yield from a stock complex in which the same overall fishing mortality capacity was allowed to distribute itself according to the relative abundance of the two, three, or five stocks in a complex, i.e. a *density-dependent distribution of fishing mortality*. The factor representing environmental variation was different for each stock within one run, but was held the same for corresponding stocks between runs to ensure that the comparisons were not biased by a particular realization of the environmental series. The potential yield under each regime was generated over 30 years, the last 10 being used as a basis for comparison, though the "fisheries" had not in all cases been stabilized by that time.

A typical example of the time series of recruitment and fishing mortality in one stock incorporating both the density-dependent recruitment and density-dependent distribution of fishing mortality is shown in Fig. 3 to illustrate the quasi-realistic situation generated by the model. Relative yields at different levels of fishing mortal-

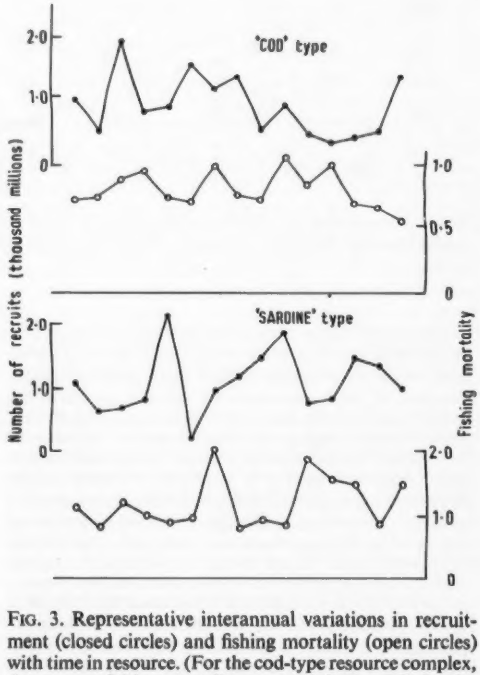

FIG. 3. Representative interannual variations in recruitment (closed circles) and fishing mortality (open circles) with time in resource. (For the cod-type resource complex, the average fishing mortality per stock is F = 0.7; for the sardine-type complex, F = 1.2.)

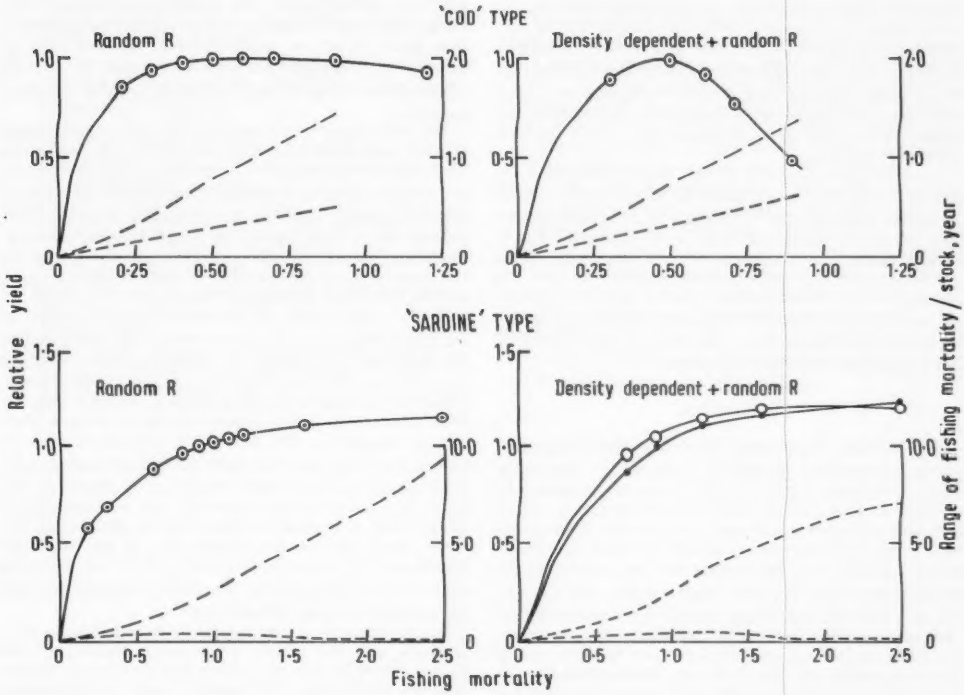

FIG. 4. Yield functions under conditions of density-independent fishing mortality (i.e. constant level of F per stock) (closed circles) and density-dependent fishing mortality per stock (i.e. varying level of F per stock) (open circles), under two hypotheses concerning the stock and recruitment relation: (i) log-normally distributed random (density-independent) fluctuations in recruitment independent of spawning stock size; (ii) log-normally distributed random (density-independent) fluctuations in recruitment superimposed on stock and recruitment relations. The pair of broken lines indicate the range of fishing mortality per average value of fishing mortality per stock, under conditions of density-dependent distribution of fishing mortality.

ity are shown in Fig. 4; this also shows the range of fishing mortality to which individual stocks became subject in individual years when the distribution of fishing mortality was density-dependent. The level of fishing mortality on individual stocks under conditions of density-independent exploitation is as shown by the scale on the abscissa.

For the complex of "cod-type" resources the yield functions for both density-dependent and density-independent exploitation were indistinguishable for each hypothesis regarding stock and recruitment. The yield functions for the "sardine-type" complex show a marginal advantage in yield to the density-dependent distribution of fishing mortality at moderate levels of exploitation.[2] Pope (In press) has explained this result, which at first appears to indicate a potential yield in excess of the maximum sustainable yield as defined by Beverton and Holt (1957). The effective selection of a cohort of fish to the fishery is the product of selection by the gear and the pattern of exploitation of that cohort with time. In the multiple-resource complex the total available fishing mortality which may be deployed on an individual stock in the density-dependent exploitation regime is high (Fig. 4). Depending upon the relative sizes of stocks in a complex, the effective age of selection of a cohort to the fishery may for a short time rise to give an effect equivalent to an increase in mesh size at a higher level of exploitation. Seen from another point of view, there are circumstances in which the gain achieved by heavy exploitation of an abundant year-class in one stock, when it is young, can outweigh the losses of failing to exploit older age-groups of other resources in the same complex. The scale of such benefit depends on the patterns of biological variability within the resource complex. In most instances, I suspect that the benefit of density-dependent exploitation in yield is probably negligible, but certainly we have not so far detected any disadvantage to the total yield in wide annual variations in fishing mortality, and this result is surprising, especially in the models presuming a density-dependent stock and recruitment relation.

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[2] The sardine-type results do not appear to be realistic, perhaps because of poor formulation of the stock and recruitment curve. Nevertheless, they serve to show an alternative to the cod-type.

A second characteristic of the density-dependent exploitation regime is its enhanced stability in yield. This is intuitively obvious, but is perhaps better illustrated by data contained in the ICES/ICNAF report on North Atlantic cod. Over the period 1955–70, the coefficient of variation in yield of individual cod stocks was 0.29; this compares with a coefficient of variation of 0.20 in catches of individual countries exploiting all or part of the resource complex whose fishing effort for cod had remained reasonably constant over the period.

Discussion

The relative importance of density-dependent and density-independent biological processes in regulating animal numbers is one of the oldest controversies in ecology. That it has not been resolved probably means that both processes are equally critical at the appropriate time in the life history of an animal, a cohort, or a population. Larkin (1963) was among the first to consider the exploitation of fisheries in the same context, and in studying its effect on interacting species he concluded that "density-dependent factors by definition will not render a population extinct, regardless of their intensity, while the same cannot be said of density-independent factors. The addition of a density-dependent factor may preserve an equilibrium that otherwise would not exist."

This he concluded in relation to density-dependent distribution of fishing mortality on interacting species. Here, I have been considering density-dependent exploitation of noninteracting species, and the same conclusion is not obvious at present. But it does appear valid that short-term variations in fishing mortality are of little consequence to total yield provided that they fluctuate around an appropriate mean level. The small distortions that appear to favor the density-dependent regime of exploitation imply that this is more efficient per unit of fishing mortality (standardized fishing effort $F=qf$).

A similar result was in fact noted with regard to North Atlantic cod resources. The particular configuration of density-dependent and density-independent exploitation in this total fishery exploits the resources more efficiently than an equivalent capacity restricted to a fixed distribution independent of the density of the component stocks. Indeed, there are resources in this complex (e.g. East Greenland), and no doubt in other resource complexes, which can be harvested only by a density-dependent regime of exploitation.

The important conclusion from this reinforces Riffenburgh's observation that multiple-stock fishery resources form a robust system; within limits they can tolerate wide variations in fishing mortality on individual stocks and, in themselves, these do not have an adverse long-term effect on the stock or its yield. The important feature is the overall mean level of fishing effort applied to the complex and, by implication, the duration over which a sustained high level of fishing mortality might be applied to one stock. From an administrative point of view of fisheries management, this also means that there is no advantage in trying to secure a precise control of fishing mortality.

The theoretical importance of density-dependent patterns of exploitation lies in the implied breakdown of the fundamental assumption that the fish/fishery interaction is a random process. Fishing concentrates where fish are most abundant, both in an integrated resource and, indeed, in a multi-age-group single-species resource. Patterns of fishing mortality generated within a stock by the same level of fishing effort therefore vary. Equally, and by definition, this means that the effective, if not the biological, catchability of the resource can be varied by the fishery itself. A notable example of this, remarked by the ICES/ICNAF group, has been the level of fishing mortality on West Greenland cod which has been maintained in the face of declining fishing activity. This has been achieved by fishing predominantly at seasons when fish are caught in the densest concentrations and by reduction of the size of the stock itself. This second point is significant in the broader context also shown by the ICES/ICNAF group with regard to cod, that catchability of the stock is inversely proportional to the area of that stock. Both observations suggest that as any stock becomes smaller its catchability will increase, i.e. given the same level of fishing effort, the fishing intensity per unit stock area (mortality) will increase.

In their model of nonrandom interaction between a resource and the fishery it supports, Paloheimo and Dickie (1964) have in fact shown that an inverse relation between catchability and overall density or abundance is to be expected, and circumstantial evidence of this must lie behind the observation by ICNAF concerning Georges Bank haddock that "catches of haddock incidental to other fisheries may be greater than annual surplus production" (ICNAF 1972). It also seems probable that trends in catchability along the lines suggested have contributed to the recent extinction of the fishery for adult Atlanto–Scandian herring. Such fisheries, in which a single-species stock is heavily predominant, are by definition exploited by a density-independent exploitation regime. Therein lies the possibility that if for some reason, natural or otherwise, the stock is reduced in size, the fishing capacity will be able to exert (and indeed, because it cannot be redeployed elsewhere, may be economically unable to avoid exerting) a higher level of fishing mortality than intended, with potentially disastrous effects. At best, if the fishery is regulated by a catch quota, the imbalance between actual capacity and allowable catch will be increased. This risk of damage caused by increased catchability is less severe when, by integration of the fishery over a number of resources, the distribution of fishing mortality can fluctuate on a short-term basis in accordance with the size of the component stocks. It provides a buffer by enabling the load of exploitation to be wisely spread. In this sense Larkin's statement, made in relation to biologically interacting species, that the "addition of a density-dependent factor may preserve an equilibrium which otherwise would not exist" may be equally applicable to interacting fisheries.

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A Gap Between Theory and Practice[1]

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Under any pooled management scheme, such as the former Blue Whale Unit system for baleen whales, it is impossible, without appropriate technological developments, to attain the theoretical maximum sustainable harvest, that is, the sum of the maximum sustainable yields which single-species theory indicates is possible. Pursuit of this maximum is likely to result in overexploitation and stock failures. In general there can be a variety of alternative targets on a sustained basis.

Regulation by area is worthy of consideration as one possible pooled management measure that will improve the sustainable harvest of the resources concerned. A set of the principles for valid area divisions is defined graphically and mathematically, although success depends on how well the proportion of each stock unit in the catch can be controlled by feasible area divisions.

Avec n'importe quel système commun d'aménagement, par exemple l'ancien système de l'Unité baleine bleue appliqué dans le cas des mysticètes, il est impossible — en l'absence de réalisations technologiques appropriées — d'atteindre le chiffre théorique des captures maximales équilibrées, c'est-à-dire la somme des rendements eumétriques que les théories monospécifiques indiquent comme possibles. En cherchant à parvenir à ce maximum, on risque de provoquer une sur-exploitation et un épuisement des stocks. En règle générale, on peut établir divers objectifs sur une base équilibrée.

La réglementation par zone mérite d'être prise en considération, car il s'agit d'un système possible d'aménagement commun permettant d'accroître l'exploitation équilibrée des ressources en cause. L'auteur présente un ensemble de principes exposés au moyen de graphiques et de calculs mathématiques, en vue d'établir des divisions géographiques valables; toutefois, leur succès dépendra de l'efficacité avec laquelle la proportion de chaque stock unitaire pourra être contrôlé dans le cadre de divisions géographiques judicieuses.

En todo programa de regulación, como el antiguo programa de la Dependencia de la Ballena Azul para la ballena de barbas, es impossible, sin un desarrollo tecnológico adecuado, lograr el rendimiento máximo sostenible determinado teóricamente, es decir, la suma de los rendimientos máximos sostenibles que el estudio teórico de cada una de las especies da como posible. Si se quiere lograr este máximo probablemente se llegará a una superexplotación, con el consiguiente debilitamiento de las poblaciones. En general, puede haber toda una variedad de posibles objetivos con carácter sostenido.

Una de las medidas de regulación que vale la pena considerar, porque tal vez pueda mejorar el rendimiento sostenible de los recursos en cuestión, es la reglamentación por zonas. Se definen gráfica y matemáticamente una serie de principios para una división válida por zonas, aunque el éxito depende de hasta qué punto sea posible controlar la proporción de cada una de las poblaciones presentes en las capturas mediante divisiones viables por zonas.

In many fishery treaties the maximum sustainable yield concept has now been accepted in defining the management objectives to meet both of the requirements, that is, conservation and maximum utilization of the fishery resources concerned. And one of the main tasks of those Commissions is to make a decision on the regulatory measures that are necessary and appropriate toward those objectives, based upon scientific assessment of the maximum sustainable yield and the present state of the stock under consideration. Generally, however, there seem to have existed significant gaps between theory and practice. It is of course logical that the biological theory of fishery exploitation should have been developed to apply to a biological unit, namely a species population that is clearly defined, at least theoretically. Any straightforward application, on the other hand, can only be valid under an additional implied assumption which has sometimes been completely ignored, that such a biological unit be independently controllable. Apparently the circumstances under which the last assumption does not hold true have been rapidly increasing, although the gap itself has always existed. In what follows, a more or less

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973

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theoretical consideration will be given to this gap and its possible implications, mainly from the viewpoint of target formulation.

The Blue Whale Unit

Let us begin with a well known example. Up to 1972 the International Whaling Commission insisted, against the repeated recommendations of its Scientific Committee, on regulating baleen whaling in the antarctic by means of a quota in terms of Blue Whale Units, which was based on oil production rates of the species of whales concerned. Apart from voting procedures, etc., the quota was determined as follows. First of all the Scientific Committee, after analyzing the available information, made a report to the Commission on the state of the stocks and an estimate of sustainable (or replacement) yield for the coming season, species by species, together with a recommendation for an immediate switchover to regulation by species. Then the Technical Committee, on the basis of the Scientific Committee's report and recommendations, made a proposal for an agreeable total quota in Blue Whale Units, based upon (though not necessarily agreeing with) the sum of the estimated sustainable yield of each species in Blue Whale Units, broadly taking into account the present condition of the stock of each species.

Setting a quota in Blue Whale Units meant giving a value of Y in function (1):

$$Y = C_B + C_F/2 + 2C_H/5 + C_S/6, \qquad (1)$$

where C_B, C_F, C_H, and C_S are, respectively, the yields of blue, fin, humpback, and sei whales, and $\frac{1}{2}$, $\frac{2}{5}$, and $\frac{1}{6}$ are the predetermined conversion factors. It is easy to see that there are a great many sets of values of the yields by species (C_B, C_F, C_H, and C_S) that will make Y equal to any given value, which is of course the reason why a quota in Blue Whale Units cannot be scientifically satisfactory.

Some years ago the taking of blue and humpback whales in the antarctic was completely banned, so let us consider what a quota in Blue Whale Units implies for the case of just two species, the fin and sei whales. Let us denote the sustainable (or replacement) yield for fins by Y_F and that for seis by Y_S (Fig. 1). The line AB, passing through the point Y_{FS} (Y_F, Y_S), represents the function (1) when it has the value Y_O (the sum of the sustainable yields in Blue Whale Units). That is, any point on this line represents a set of yields, by species, the sum of which in Blue Whale Units has the value of Y_O. Therefore, setting a quota in Blue Whale Units means choosing a line that is parallel to AB in the figure.

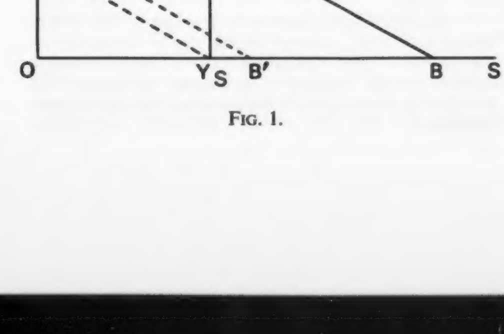

FIG. 1.

The report of the Scientific Committee indicates that fin whales in the antarctic are at a level considerably below the level giving the maximum sustainable yield, and that the catch must be as much lower than the estimated sustainable yield as possible to achieve effective stock recovery. Sei whales, on the other hand, are somewhat above the level that gives maximum sustainable yield, and the catch can be allowed to exceed the sustainable yield for a few more years, but soon it should not be allowed to be greater than the (maximum) sustainable yield. It is evident from Fig. 1 that, even if the quota in Blue Whale Units be set a good deal lower than Y_O, there will be choices available in which the function crosses the line Y_FY_{FS} (that is, choices that allow the fin whale catch to exceed its sustainable yield), unless the quota be set a great deal lower than Y_O. Therefore, if conservation requirements for the fin whale are to be guaranteed, the quota must be set equal to, or lower than, the value indicated by the line Y_FB', that is, the estimated sustainable yield for fin whales alone. Further, when sei whales will have been reduced to the level giving maximum sustainable yield, the quota in the Blue Whale Units will have to be set at, or lower than, the value indicated by the line segment $A'Y_S$, which is the maximum sustainable yield for sei whales alone.

The management target can be considered in the same way. It may be simpler than in case of dynamic decision-making, because it is unnecessary to take into account the present state of the stock relative to the level giving maximum sustainable yield. Read Y_F and Y_S in Fig. 1 as the maximum sustainable yields of fin and sei whales, respectivley. Consider the rectangle $OY_FY_{FS}Y_S$ to represent the set of stable sustainable yields[2] of both species. From the above it is already clear that to formulate a management target in Blue Whale Units is to choose a value of the function (1), that is, a line parallel to AB. Then, in order for the target to meet the requirements both of conservation and of maximum utilization, it must be set at the lower of the two maximum sustainable yields in Blue Whale Units for each species concerned, which in this case is the maximum sustainable yield for the sei whale. In general this will necessarily maintain both of the stocks in a state of underexploitation, for any higher target would threaten one or both of the stocks with overexploitation.

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[2] Under fairly wide conditions the sustainable yield of a stock will have its maximum at an intermediate level of stock abundance. In other words, there are usually two stock levels that can produce any given sustainable yield (except the maximum). From a dynamic point of view, however, the sustainable yield at the higher of these two levels (the one which is greater than the level giving the maximum sustainable yield) is stable against any disturbance, while that at the lower level is unstable in the sense that a disturbance will give rise to a continuing change in the stock level in either direction.

The above reasoning as regards target formulation may sound strange or even absurd, especially if it is kept in mind that selective catching of the larger whale species is quite possible in modern whaling.

Notice, however, that it results from characteristics that are inherent in regulation by Blue Whale Units, which in principle leaves to the industry a completely free choice of species within the overall quota. It seems that an unfortunate impression has prevailed rather generally, that fishery management not only restricts operational freedom in various ways but also necessitates a drastic limitation on the level of production, so that it interferes with possible fishery developments. And in fact there have been individual cases where the circumstances were such that this could not be helped. But fundamentally fishery management means a deliberate coordination of human effort toward a stable growth of fishery production, for otherwise it could scarcely command progressive social support. Hence in the above reasoning there is nothing strange or absurd at all; rather it is completely on target. To be wise after the event, the baleen whale situation might have developed more rationally if the Scientific Committee's annual recommendation for regulation by species had been coupled with the additional advice that if the Blue Whale Unit had to be retained, the permissible quota would have to be reduced to the sustainable yield in Blue Whale Units of the fin whale alone. At its 1972 meeting the International Whaling Commission finally abolished the use of Blue Whale Units for quota purposes.

Pooled Management

In addition to the Blue Whale Unit in antarctic whaling, there seem to be a good number of examples of very similar management schemes applied to fish stocks. A plain case of this, and an extreme one in a sense, is the pooled management of several unit stocks of the same species.

Naturally, biological theory and research have developed more or less exclusively in terms of a biological unit, either a species population or (if such exists) a subpopulation unit within a given species. The first task in most fishery-biological research is usually to define the biological unit under consideration. A great many research contributions can be classified as, or at least are partly concerned with, "Stock Identification." Each of them has its own raison d'être in the domain of research, but unfortunately it is often not at all obvious how these contributions can be fitted into management practice. Often, it would seem, theory does not adapt itself to realities; rather the realities are forced to shape themselves in accordance with theory.

The circumstances under which several unit stocks are pooled for management doubtless differ from case to case. Several examples can be found in salmon fisheries or in whaling. No doubt there are similar examples elsewhere, but in those cases the existence of distinct stock units is not always well demonstrated.

An essential difference between ordinary pooled management and the case of the Blue Whale Unit is that selective removal such as is possible for whales will be technically difficult or impossible. The proportion in the catch of each unit of stock depends on interactions between ecological features on the one hand and fishing operations on the other. Without any ecological information this will be determined by ecological features within the range of fishing operations. As information increases, the industry will have available a wider choice of stock units. In any event it can be assumed that in a given situation the proportion of each unit of stock in the catch can be fixed; or more generally that it will lie within a fixed range because of natural fluctuations and/or choices on the industry side. Moreover, generally speaking, there is no guarantee that the ratio of sustainable yield to stock is the same even for different units of the same species[3], although this seems often to have been too readily assumed. Therefore, even apart from dynamic situations, the proportion in the catch can hardly be expected to coincide with the proportion of the maximum sustainable yield for each and every stock present.

Now let us for simplicity restrict ourselves to the problem of target formulation and consider, without any loss of generality, a two-dimensional case, that is, the pooled management of two stock units of the same species. Suppose the proportion in the catch can be fixed by OP in Fig. 2-1, then it is evident from the Figure that the sum of the maximum sustainable yields for each is unattainable as a target; in other words, pursuit of it as a target means failure of conservation of one of the stock units, namely S_1 in the case of Fig. 2-1. The feasible target catch level must be reduced to the level indicated by the line AB in order for the target to meet the requirements both of conservation and of maximum utilization.

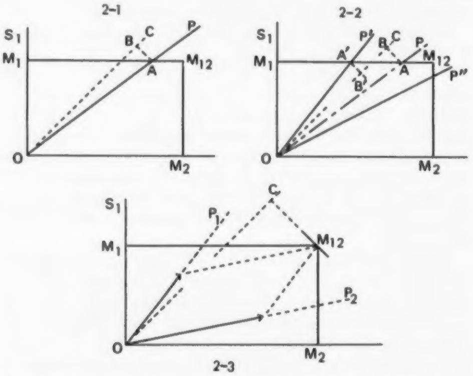

FIG. 2. Pooled management of two stock units of one species at various rates of exploitation. (OC bisects the coordinate axes scaling the pooled catch level.)

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[3] A generally applicable curve familiar to the fishery biologists is the yield-per-recruit curve. However, its authors have never guaranteed any agreement among different stocks, because they merely formulated the problem in that way by leaving recruitment out of consideration.

If *n* units of stock are involved the same is true, but here pursuit of the sum of the maximum sustainable yields as a target will bring about an increasing variety of failures in conservation, depending on the relation of the proportion in the catch to the proportion of maximum sustainable yield for each. Conversely, it may happen that insistence on the conservation requirement for all units leads to an absurd target, because then the feasible target will be constrained by one of the stock units which might happen to be the least productive component. Generally speaking there can be a variety of alternative targets on a sustained basis.

Suppose, more generally, that the proportion in the catch be in some degree indeterminate, for whatever reason, so that it lies within the range OP′ to OP″ of Fig. 2–2. Let the fixed proportion used above fall between these two, on the average; then evidently the feasible target catch level must be further reduced in order to meet both of the requirements.

A common, and probably ancient, management practice under such circumstances is to have a division by areas and/or seasons. For simplicity, suppose that the proportion of each stock unit in the catch can be fixed in each such division. If the whole area be divided into subareas 1 and 2, and the proportion in the catch in those subareas can be fixed at OP_1 and OP_2, respectively (Fig. 2–3), then it is evident by the rule of vector sums that the sum of the maximum sustainable yields for each will be attainable as a target by using such an area division.

Suppose that both of the proportions in the catch in the two subareas are either above or below the proportion of the maximum sustainable yield for each; then the sum of the maximum sustainable yields for each is still unattainable as a target. Also suppose that the whole area be divided into more than two subareas, say three subareas, then there arise two alternative cases: one is, the proportion of maximum sustainable yield for each falls outside of the range of the proportions in the catch of each stock unit in those three subareas, and the other is the case where it falls within the range. The former is the same as the case immediately above. In the latter case, the sum of the maximum sustainable yields for each will be attainable as a target, although the distribution of the catch between the three subareas can be more or less flexible. Summing up in more general terms, the conditions for valid area divisions are: (1) When *n* units of stock are involved, it is necessary to divide the whole area into at least *n* subareas, in which the proportions in the catch of each unit of stock will meet condition (2) below. If the whole area be divided into more than *n* subareas, the distribution of the target catch can be somewhat more flexible than otherwise. (2) Between the proportions in the catch of any two stock units in any two of the *n* subareas must lie the proportion of maximum sustainable yield for the two stock units.

Difficult though this may sound, what it means essentially is that the whole area must be divided into *n* subareas so that each subarea will include one of the main fishing grounds for each stock unit. Thus it is likely that almost all intuitive area divisions have met this condition. However, one thing to notice is that the main fishing ground for each unit is here defined not by the fraction of the total catch that is taken there, but with reference to the proportion of the maximum sustainable yield for the stocks units involved.

In the above it has been assumed for simplicity that the proportion in the catch of stock units can be fixed for each subarea. More generally, if it be indeterminate within a fixed range, the sum of the maximum sustainable yields for each stock would be unattainable no matter what the division by area (or season), as suggested earlier. However, regulation by area remains worthy of consideration in a pooled management scheme as one of the possible means of improving the feasible target level of catch, insofar as the proportion in the catch can be successfully controlled by the mechanism. How to calculate the feasible target catch level under these circumstances is shown in the Appendix for the simplest, two-dimensional case. Any more general case can be easily solved by an electronic computer.

DYNAMIC SITUATIONS

For more dynamic annual decision-making on regulatory measures, additional information is needed on the present state of each unit of stock, that is, the present stock level relative to the one giving the maximum sustainable yield, and also the present sustainable (or replacement) yield. This information will determine the immediately allowable catch for each stock unit. For example, suppose that stock 1 has been overexploited and stock 2 underexploited, and denote their present sustainable yield by Y_1 and Y_2, respectively, in Fig. 3; then the immediately allowable set of catches is represented by the shaded rectangle. The basis for a valid division into areas is then the proportion of the present sustainable yield for S_1 to the maximum sustainable yield for S_2. Of course, because of the changing situations that have to be met, decisions will have to be reviewed and if necessary modified, either annually or at some other specific time interval.

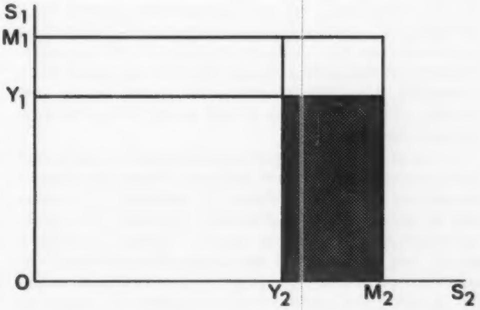

FIG. 3.

Additional Remarks

1. The salmon fisheries referred to as an example of pooled management have two distinctive features from the management viewpoint. One is that the stocks are generally available to commercial fishing only for a short period of their lives on the way back to the spawning grounds. Therefore management has been exclusively concerned not with the problem of growth-mortality balance but with parent–progeny relations. And there, broadly speaking, a management failure in escapement (parents) in one year will some years later be reflected in the progeny. The other feature is that because of a fairly well-established homing tendency there are usually so many biological units of stock even in a single river system that management cannot avoid pooled schemes, in varying degree. What happens under such circumstances has already been indicated above. Actually a great many spawning grounds have been documented, for example along the Pacific coast of North America, but the history there suggests that management has never attempted to achieve the unrealistic, and actually dangerous, target of the maximum sustainable yield for all such stocks simultaneously. Instead, it appears to have tolerated major year-to-year fluctuations, induced not only by natural factors but by the management practice itself. And in spite of the enormous effort expended, it still seems unclear what management has been attempting and what it will do in future. A review and clarification of these matters is the prime requisite for rational development.

2. As regards whaling, the Blue Whale Unit has at last been abandoned in favour of regulation by species, but it is to be noted that there is still only a single quota for each species in the whole antarctic. Some studies indicate that several stock units occur in the antarctic for each species, although their demarcation is not yet clearcut. On the other hand, because quotas have recently been decreasing it is getting difficult to expect the fishing effort to extend over the whole antarctic as it did formerly. Therefore it may prove that some units are much more vulnerable than others, unless the quota be set low enough, or unless there is a shift to regulation by area for each species.

3. The principles for valid area division may be applied in management of the trawl fisheries, though the circumstances are somewhat different. It appears that regulation by species has predominated, probably as a logical consequence of biological studies. Although logically sound, this by itself will not always be satisfactory in practice, except when the single species stock concerned can be controlled independently of others. For example, until the 1950s the North Pacific halibut fishery had developed as a unit, by improving its own gear's selectivity for halibut and by discouraging any other fisheries that might take appreciable numbers of halibut. Such happy circumstances, however, seem to be disappearing. And in trawl fisheries obviously no single species stock can be independently controlled. They are not under any pooled management scheme, to be sure, but it would be difficult to attain the target of maximum sustainable yields by species simply by leaving free choice to the industry.

4. Regulation by area has its own problems, notably in the matter of enforcement. And industry may well be reluctant to agree to such area regulation as is necessarily accompanied by supplementary enforcement measures. A good deal of the difficulty, however, can be overcome by the introduction of some kind of automatic monitoring system.

Appendix 1. Solving the Case Where the Proportion in the Catch of Each Stock Unit Lies Within a Known Range

In the case where the rate of exploitation of each stock unit is variable and indeterminate within a range, there are several ways of obtaining a set of feasible catch levels in each subarea so as to meet the requirements of conservation and maximum utilization. Here a geometrical procedure will be used, for better understanding of the basic reasoning.

Denote the proportion of each unit of stock(s) in the subarea (a) by r_{asi} (a,s,i = 1,2; $r_{a1i} + r_{a2i} = 1$), and suppose it to be independently variable from (r_{111}: r_{121}) to (r_{112}: r_{122}) in Subarea 1 and from (r_{211}: r_{221}) to (r_{212}: r_{222}) in Subarea 2. Denote the overall catch level in the subarea (a) by $C_{a.}$ ($a.$ (a = 1,2). Then a set of the catch by unit of stock (C_{11}, C_{12}) in Subarea 1 is represented by the line segment A_1A_2, and the points (C_{21}, C_{22}) in Subarea 2 by the segment A_3A_4 in Fig. 4. And the set of the catch by unit of stock in the whole area ($C_{.1}$,$C_{.2}$) is represented in the same figure by the line segment $X_{13}X_{23}X_{14}X_{24}$, where these four points are on the same line.

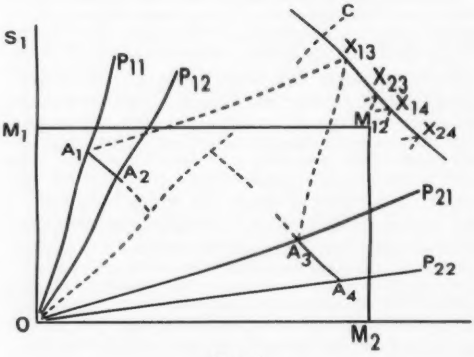

FIG. 4.

Denote the maximum sustainable yield for each unit of stock by M_s (s = 1,2). Then in order for the set of the overall catch level in each subarea ($C_{1.}$,$C_{2.}$) to meet the conservation requirement, the last segment X_{13}.. X_{24} must lie inside of the rectangle $OM_1M_{12}M_2$, closed by the two coordinate axes and $C_{.1} = M_1$ and $C_{.2} = M_2$. In other words, as is evident in the figure, the $C_{.1}$–coordinate or $C_{.2}$–coordinate of the end points X_{13} and X_{24} of the segment must be equal to, or less than, M_1 or M_2, respectively. The set of the overall catch level in each subarea $(C_{1\cdot}, C_{2\cdot})$ qualified for these two inequalities, that is, the conservation requirement, is represented by the shaded tetragon in Fig. 5. The total catch, that is, the function $C_{\cdot\cdot} = C_{1\cdot} + C_{2\cdot}$ has its maximum or its minimum at an apex of the tetragon. In case of Fig. 5 it evidently has its maximum at the apex opposite to the origin.

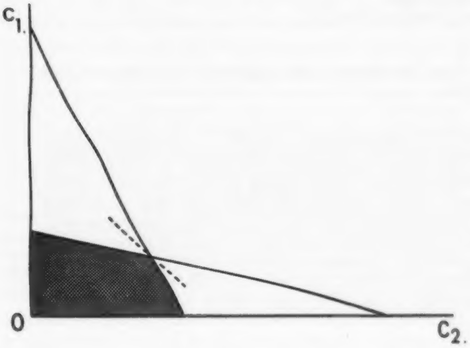

FIG. 5.

NUMERICAL EXAMPLE

Suppose the rate of exploitation of each unit of stock to be variable and indeterminate as follows:

Subarea 1 — 95 to 80%
Subarea 2 — 35 to 10%

Assume that the maximum sustainable yield is 5000 tons for stock 1 and 7000 tons for stock 2. Then the $C_{\cdot 1}$–coordinate of the end point X_{13} and the $C_{\cdot 2}$–coordinate of X_{24} must meet the following inequalities:

$$0.95\,C_{1\cdot} + 0.35\,C_{2\cdot} \leq 5000$$
$$0.20\,C_{1\cdot} + 0.90\,C_{2\cdot} \leq 70000$$

Solving these inequalities to maximize $C_{\cdot\cdot}$ $(= C_{1\cdot} + C_{2\cdot})$, we have:

$$C_{1\cdot} = 2611, \text{ and } C_{2\cdot} = 6478$$

The total yield is therefore 9089 tons.

If the rate of exploitation were determinate, $C_{\cdot\cdot} = 12{,}000$ tons in total could be realized as a target. Of course such a reduction depends on the variability, or controllability, of the proportion in the catch of each stock unit.

Sequence of Exploitation of Stocks in Multispecies Fisheries in the Laurentian Great Lakes[1]

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Regier, H. A. 1973. Sequence of exploitation of stocks in multispecies fisheries in the Laurentian Great Lakes. J. Fish. Res. Board Can. 30: 1992–1999.

The Laurentian Great Lakes have been fished with gradually increasing intensity for about 150 years. Their fish communities have been stressed by a broadening variety of other cultural influences besides fishing. A series of recent analyses have identified and distinguished effects due to fishing from those due to other cultural stresses. These analyses are here carried a step further, showing the fishing-up and overfishing sequence, through time, of various species as a function of their economic value to the fishermen. Some elements of a theory are proposed that interrelate a number of whole-system variables; if elaborated further such a theory should be useful in modelling and managing competing fisheries that harvest a number of ecologically interrelated species, perhaps more or less indiscriminately. Further, the theory should permit modelling and managing of other cultural stresses on the fish community, such as nutrient loading and toxic pollution that may act contemporaneously with fishing.

Les grands lacs des Laurentides font l'objet d'une exploitation de plus en plus intense depuis environ 150 ans. Une gamme toujours plus grande d'activités humaines, sans oublier la pêche, soumet leurs populations ichtyologiques à diverses agressions. Une série d'analyses récentes a permis d'identifier et de classer les incidences dues à la pêche et celles imputables à d'autres contraintes d'origine humaine. Ces analyses sont ici poussées plus avant afin de démontrer la succession dans le temps des différents types d'exploitation – relance ou surexploitation – des espèces en fonction de leur valeur économique pour les pêcheurs. L'auteur propose divers éléments d'une théorie, visant à établir une corrélation entre un certain nombre de variables au sein d'un même système; une telle théorie, si elle était approfondie, devrait permettre d'établir des modèles et des plans de gestion pour les pêcheries concurrentes qui exploitent, avec plus ou moins de discernement, un certain nombre d'espèces interdépendantes sur le plan écologique. Cette théorie devrait permettre en outre de déterminer et d'organiser les autres contraintes pouvant être exercées en même temps que la pêche sur les populations de poisson, telles que la charge nutritive et la pollution de caractère par des substances toxiques.

Durante unos 150 años los Grandes Lagos Laurentinos han sido objeto de una explotación que gradualmente ha aumentado en intensidad. Además de la pesca, sus poblaciones ícticas han estado sometidas a varias influencias. Una serie de análisis recientes ha identificado y separado los resultados obtenidos con la pesca de aquellos otros producidos por otras actividades de cultivo. Estos análisis se estudian en este documento aún más, poniendo de relieve a través del tiempo, las fases de explotación máxima y superexplotación de las diversas especies, en función de su valor económico con respecto a los pescadores. Se proponen algunos elementos de una teoría que relaciona entre sí diversas variables de la totalidad del sistema; si esta teoría se perfeccionara más tendría utilidad para estructurar y reglamentar las pesquerías competitivas que capturan un cierto número de especies ecológicamente interrelacionadas, de manera más o menos indiscriminada. Además, esta teoría permitiría la estructuración y reglamentación de otras tensiones de cultivo a que están sometidas las poblaciones de peces, como son los elementos nutritivos y la contaminación tóxica, que pueden actuar contemporánoamente con la pesca.

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

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Types of Fishery Resources

CONVENTIONAL wisdom implies that fisheries resources should be developed and managed using a multidisciplinary multistage decision process, or gaming procedure, in which the decision rule will likely change through time. Given a large homogeneous resource that is relatively isolated from other resources both ecologically and culturally (i.e. with respect to socioeconomic factors), dynamic programming and functional modelling methods appear to be sufficiently well developed to deal effectively with ecological aspects, and perhaps with considerations in some other disciplines. Alternatively, given a regional fishery that exploits hundreds of small bodies of water thoroughly intermixed with other small enterprises on water and land, conventional agricultural approaches to development and management, or regional planning methods, may now be adequate. Between the two extremes of a large functionally isolated resource and a functional mosaic of many small resources some of which are fisheries, are a large number of fisheries too small to justify the expense of ongoing formal dynamic programming but too large to treat simply as replicated units complementing or competing with replicated units of other resources.

The quantitative theory and sampling techniques appropriate for assessing the potential value of a "major stock" as an unexploited resource, and for guiding exploitation practices in a simplified multistage decision process, have become well developed in recent decades. In practice "major stock" implies a large single-species mass that is fairly "stable" or unresponsive under exploitation pressure and is either ecologically dominant or functionally isolated from other "major stocks."

Pond-fish culture industries, or farm ponds as agricultural or recreational resources, in effect use whole-system ecological indices. To the extent that these resources have been dealt with scientifically, the indices have been calibrated using data from stratified and replicated experiments and sample surveys.

Medium-scale resources (e.g. stocks), though always recognized as being functionally influenced by other stocks in the same body of water, nevertheless could often be treated at low to moderate fishing intensities as though they were isolated. In such cases all the various interactions that were assumed away were either well behaved or of minor effect as perceived in the particular model selected. As fisheries have become more intensive on particular stocks and have spread to more and more stocks in a body of water, the simplifying assumptions have come to be seriously violated. Other fisheries even from their beginnings were never of the "dominant or functionally isolated stock" variety.

If the above analysis is a reasonable one, then it follows that a large and growing proportion of the world's fisheries yield derives from resources for which fisheries science does not as yet have fully appropriate models or efficient techniques for practical management purposes.

Medium-sized fisheries in many of the larger lakes of the world have long since reached intensities and complexities that made those fisheries intractable to simple conventional approaches. We have examined the history of Lake Erie and its fisheries and particularly from this viewpoint (Regier et al. 1969; Regier and Hartman 1973;) and I judge that events in Lake Erie's fish community and fisheries since about 1890 could not have been dealt with effectively even using the theory and techniques of the 1960s. Case histories of other lakes (see Loftus and Regier 1972) bear out this judgement.

Various aspects of our difficulties with conventional fisheries theory and methods have been examined elsewhere (Regier and Henderson 1973). Here I shall summarize what has emerged from analyses of the case histories of a number of large lakes, using Lake Erie as an example. Secondly I will sketch a context that may permit more efficient modelling and managing of fisheries that appear complex using the conventional approaches. The perception of complexity as such may stem either from the fact that a number of species are harvested concurrently and perhaps opportunistically, or from progressive changes in the fishes' environments due to other cultural stresses (industrial waste and nutrient loading, engineering works, sedimentation, etc.).

An Example of Fisheries on Large Lakes

There has long been confusion on the separate and joint effects, so-called "indirect effects," of major users of aquatic ecosystems. Some clarification of their effects on fish resulted from a 1971 symposium on the subject (Loftus and Regier 1972); in the light of those insights we have reexamined Lake Erie's events (Hartman 1972; Regier and Hartman 1973).

Figure 1 depicts annual catches of a number of taxa in Lake Erie. Dotted outlines are based on our interpretations of fragmentary reports in the older literature. Dashed outlines are based on quite reliable annual reports from the Canadian side and less frequent reports — usually from decennial census surveys — from the American side. Continuous outlines stretch over years for which complete commercial catches were reported from all political subdivisions of the lake. Angling catches have not been included — their addition would alter the picture only slightly, considering the ordinate scale used in the figure.

A number of species are not included in Fig. 1. The smallmouth bass was reserved as a sport fish at the turn of the century; a moderate commercial fishery on it ceased at that time. The common carp has been moderately abundant since its introduction in the 1880s. The white bass has erupted occasionally during the past two centuries.

The smelt was introduced elsewhere in the Great Lakes watershed and then invaded Lake Erie. The *Stizostedion* species include the sauger, walleye, and blue pike whose histories in the fishery differed considerably from each other (see Table 1); they are lumped here because reliable separate statistics are available only since 1915. The ictalurids include the channel catfish and brown bullhead, whose histories have not differed markedly.

As concerns major stresses on the fish component of the Lake Erie ecosystem, the evidence appears clearly to indicate that the *dominant* (though not the sole) impact until about 1945 was the commercial fishery. It was largely unregulated and opportunistic. Between 1945 and 1955 the piscivorous pelagic rainbow smelt became an important species in the lake; also the rapidly increasing rates of nutrient loading, mostly from urban domestic sewage,

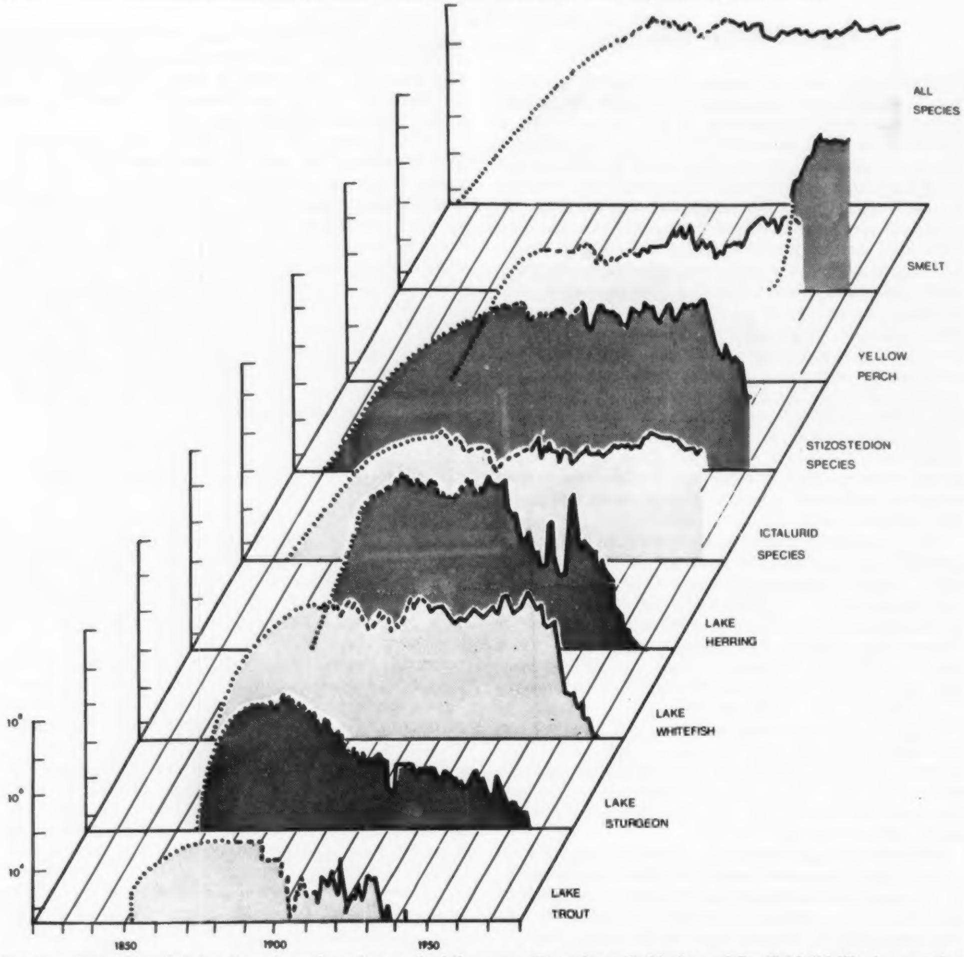

FIG. 1. Lake Erie fish landings by selected taxa, in kilograms. Data from Baldwin and Saalfeld (1962) plus supplements, and early reports in the literature. (From Regier and Hartman 1973.)

caused the hypolimnion of the large central basin to become anoxic. After about 1950 the opportunistic fishery, nutrient loading, and the predatory habits of the smelt appear to have acted synergistically to effect a profound change in the fish community by 1960. There has been no effective relaxation of any of these stresses since then and no recovery of the fish community. If in addition the hypolimnion of the eastern basin continues in its rapid trend toward summer anoxia, then the few members of cold stenothermic species that still persist there will predictably be exterminated.

Figure 1 shows that lake trout, though never abundant, were reduced to insignificance prior to 1940. The lake sturgeon yielded only small catches, about 1000 kg, by 1940. The fishery was largely responsible for suppressing the lake trout and lake sturgeon.[2] The lake whitefish, lake herring, and *Stizostedion* spp. fluctuated in abundance since 1890, and collapsed following 1950. Fluctuations were likely induced and paced by fishing stress, and the more recent collapses by combinations of the three major stresses. Ictalurids continued to thrive under a traditional fishery of moderate intensity in the greatly enriched, shallow western basin. Smelt, yellow perch, sheepshead (not shown), and white bass (not shown) thrived particularly after 1950. Total catch of all commercial species combined has remained more or less constant since 1880.

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[2] There is a large literature on these and related subjects; the most pertinent references may be located through the SCOL symposium proceedings (Loftus and Regier 1972).

Table 1. Value of landed catches, by decades, of Lake Erie. Value in thousands of 1970 US dollars based on average 1790 US prices for whole weight fish as paid to fishermen, S = small amounts. (Catch data from same sources as Fig. 1; prices from US National Marine Fisheries Service; calculations by W. R. MacCallum.)

	1851 1860	1861 1870	1871 1880	1881 1890	1891 1900	1901 1910	1911 1920	1921 1930	1931 1940	1941 1950	1951 1960	1961 1970
Brown bullhead	88[a]	364[a]	661[a]	163	65	32	72	48	74	78	52	26
Channel catfish				737	293	143	316	181	180	334	740	451
Common carp	0	0	0	40	82	337	429	152	145	117	197	183
Goldfish	0	S	S	S	S	S	S	S	8.6	4.4	6.3	8.2
Lake herring	<800	<800	828	2829	3665	1702	3046	1318	85	312	21	S
Lake trout	29	39	72	76	44	7.4	5.85	5.33	2.1	0.26	0.024	S
Lake whitefish	123	706	1647	1823	937	1095	1772	938	1486	2239	672	4
Sheepshead	S	4.1	14	25	37	63	120	123	144	186	185	189
Rainbow smelt	0	0	0	0	0	0	0	0	0	S	44	610
Lake sturgeon	S	737	2345	3460	1409	293	66	61	47	31	18	2
Suckers	S	S	S	S	59	64	57	54	64	26	21	12
White bass	<200	<200	<200	<200	<200	<200	117	116	214	252	1100	670
Yellow perch	S	9.7	183	437	497	297	440	948	1460	646	1396	4002
Walleye	231[b]	1280[b]	2870[b]	1064	700	745	688	747	1307	2193	4113	526
Blue pike				2400	2185	2718	3272	4159	5271	4851	3613	0
Sauger				1499	1091	659	1307	642	442	198	45	0
Total	>471	>3140	>8619	>14,159	>10,800	>8064	>12,034	9543	10,929	11,467	12,453	6680

[a] Ictalurids combined.

[b] *Stizostedion* spp. combined.

Table 1 shows the calculated values of catches in successive decades to the fishermen (landed value) in terms of 1970 US prices and 1970 US dollars. The peak value as estimated occurred in the 1881–90 decade. Catches in that decade may yet have contained some of the "capital" biomass taken during any fishing-up sequence. Catches of smallmouth bass, northern pike, and snapping turtle that were taken in considerable numbers until about the turn of the century would increase the value for 1881–90. We do not have reliable data on catches of those species. Altogether I judge \$12–14 $\times 10^6$ (1970 US dollars) to be reasonable estimates of the value of the sustained annual catch if the species in the fishery in 1880, and other aspects of Lake Erie, could have been managed and conserved.

By 1900 the fishery was generally recognized as overly intensive; some fisheries had been forced into bankruptcy and others relocated to less heavily fished lakes. Some regulations restricting catches were enforced on all parts of the lake by 1905; the low catches during 1901–10 reflect both depressed stocks and reduced effort. Restrictions were largely relaxed for patriotic reasons during World War I resulting in increased catches. During the next decade a very efficient new gear, the bull-net, was used widely, but the value of catches dropped. The bull-net was outlawed but World War II again resulted in a relaxation of new regulations. Greatly increased nutrient loading in the 1940s and 1950s presumably increased ecological production of fish; the introduction of gear with synthetic fibres in the 1950s permitted high catches. The new species that now dominate the community, following the ecological transformation effected in 1945–55, are low-valued hence the total value of the catch in 1961–70 is the lowest of the 10 decades since 1870, though biomass of annual catches has remained high.

The three major stresses acting in Lake Erie's fish community have separately and jointly acted to alter the community from one dominated by large benthic forms to small pelagic forms (Regier and Loftus 1972; Regier 1972). One of the consequences is an increased variability in year-to-year landings of particular species, which implies increased year-to-year social and economic risk. Secondly, the small pelagic forms have generally a lower market value per unit biomass than larger benthic forms (Fig. 2), and fishing and processing costs for smaller fish may be higher on average. The consequence is that a few highly mechanized, capital-intensive enterprises have displaced the many labor-intensive firms of earlier years.

It may come as a surprise that the greatly increased nutrient loading and phytoplanktonic production in recent decades has not led to greatly increased fish yields, particularly since smaller, "more efficient" fish species now dominate the community. It is true that more biomass could be removed, particularly of the sheepshead that is now deemed nearly worthless. Even so, their contribution would not increase catches by more than 25%. From these and other data I have inferred that notions based on simple trophic dynamic concepts can be quite unreliable (Regier 1972).

The picture here sketched of Lake Erie ignores a great amount of published detail almost all of which I interpret to be consistent with this broad analysis. In such a broad context Lake Erie appears typical of other large lakes in North America and Europe.

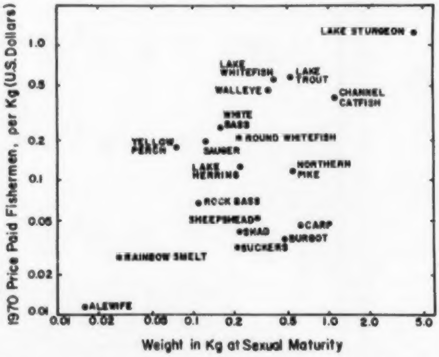

FIG. 2. Value to the fishermen (1970 US prices) of a kilogram of fish whole weight as a function of the average size of a species at sexual maturation. (Calculated by J. G. Lark).

Almost without exception it has been impossible to regulate fishing intensity or other major stresses. Attempts to control effort in any number of the conventional ways have failed, either because they could not be enforced, or because they were not sufficiently comprehensive, or both. Innovation has apparently never been forbidden, that is, "catchability" has been ignored. Without such control, attempts at "effort control" appear doomed at the outset.

Case histories of man's impacts on many lakes appear to resemble those of shelf seas. Lakes are smaller, more accessible; transformations due to cultural processes have progressed much further in many of them than in any of the major shelf areas. In some cases nutrient loading stresses are again being relaxed (e.g. Lake Washington, Lac d'Annecy) and the ecosystems are beginning to recover some of their earlier characteristics. Large-scale experiments that reduce fishing stress in order to model and measure relevant recovery processes are long overdue. Lakes would appear to be appropriate places to do such experiments, particularly in countries whose markets are already glutted with animal protein.

I believe that the proposal outlined in the next section is consistent with the approach of Henderson et al. (1973). Introductory considerations may be found in Regier and Loftus (1972) and Regier and Henderson (1973). Many of the details will not be elaborated here.

A Theoretical Context Useful for Management

I feel that an efficient way to proceed, in fisheries research on medium-sized and/or "complex" fisheries, is to use existing whole-system theory and extend it further. So far, fisheries theory has been largely limited to populations; we should now deliberately direct attention at the fish community and ecosystem as such.

In particular, the concept of ecological "succession" may be useful. Odum (1969) has used the succession concept to interrelate in a semiquantitative manner some of the whole-system variables already researched to some extent by ecologists (Table 2).

TABLE 2. A series of variables appropriate for a macroscopic analysis of ecosystem characteristics and processes as interrelated in the context of the succession phenomenon (from Odum 1969[a]).

Ecosystem variables	Developmental stages	Mature stages
	Community Energetics	
1. Gross production/community respiration (P/R ratio)	Greater or less than 1	Approaches 1
2. Gross production/standing crop biomass (P/B ratio)	High	Low
3. Biomass supported/unit energy flow (B/E ratio)	Low	High
4. Net community production (yield)	High	Low
5. Food chains	Linear, predominantly grazing	Weblike, predominantly detritus
	Community Structure	
6. Total organic matter	Small	Large
7. Inorganic nutrients	Extrabiotic	Intrabiotic
8. Species diversity–variety component	Low	High
9. Species diversity–equitability component	Low	High
10. Biochemical diversity	Low	High
11. Stratification and spatial heterogeneity (pattern diversity)	Poorly organized	Well-organized
	Life History	
12. Niche specialization	Broad	Narrow
13. Size of organism	Small	Large
14. Life cycles	Short, simple	Long, complex
	Nutrient Cycling	
15. Mineral cycles	Open	Closed
16. Nutrient exchange rate, between organisms and environment	Rapid	Slow
17. Role of detritus in nutrient regeneration	Unimportant	Important
	Selection Pressure	
18. Production	Quantity	Quality
	Overall Homeostasis	
19. Internal symbiosis	Undeveloped	Developed
20. Nutrient conservation	Poor	Good
21. Stability (resistance to normal external perturbations)	Poor	Good
22. Entropy	High	Low
23. Information	Low	High

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Unfortunately, the term "succession" connotes different processes to different people. (a) The most common — and potentially most confusing – use relates to the geological sequence in which a lake gradually fills up, becomes a marsh and dry land. This "geological succession" causes a lake to exhibit some of the same effects as an increase in nutrient loading, i.e. "eutrophication." It happens that "morphometric eutrophication" appears to be a typical natural aspect of geological succession of a lake, while "nutrient oligotrophication" is a typical, natural aspect of a particular kind of the "ecological succession" of a lake of fixed morphometry. (b) If excessive cultural nutrient loading is reduced in a lake, other factors remaining constant, then oligotrophication is part of the healing process following the relaxation of that stress. Conventionally, ecological "succession" connotes a healing process that follows relaxation of a particular kind of stress; I propose that the concept be generalized to include the recovery sequences that follow relaxation of any kind of stress, or, for that matter, that follow a change in one or more major variable affecting the community. (c) A third use of the term "succession" relates to the sequence of community responses, or pathology, as a man-induced, cultural stress intensifies. This third use of the term is in essence directly contradictory to the usual and preferred meaning. To emphasize, I use "ecological succession" in the sense of a community's reponse to a relaxation of a stress, whether of natural or cultural origin.

These concepts may be explained further with the aid of Fig. 3. The measure of "well-being" could be an index of: diversity; stability-persistence; stability-resilience; stability-homeostasis measuring, say, the degree of responsiveness to standardized stress; or some function of these — Margalef (1969) has discussed some of the possibilities.

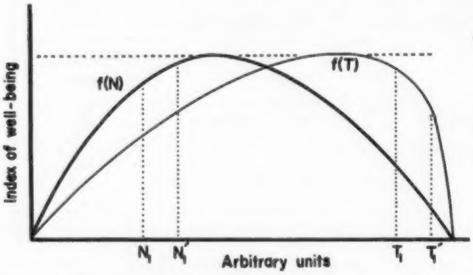

FIG. 3. Model of well-being of a community.

The model in Fig. 3 is as follows. The curve *f*(N) measures well-being as a function of environmental factor N where the other environmental factor T is optimal. Similarly for the curve *f*(T). N and T are taken to be independent dimensions, here superimposed in a plane. Community well-being is a joint function of N and T; most simply $W = f(N) \cdot f(T)$, if the ordinate is scaled from 0 to 1. For any real case the model should be more complex and the following points would need to be developed in rather more detail.

With the simple model, assume a steady state system subject to factor levels N_1 and T_1. Suppose the ecosystem is "stressed" by increasing N to N_1', other factors remaining fixed; the consequence is that well-being rises. If the stress is subsequently relaxed and assuming that no irreversible change has been caused by the stress, then a drop in well-being will result. It is clear that the use of "stress" in this generalized sense tends to conflict with conventional use where stress is often seen to lead only to adverse consequences.

Instead of changing N, suppose T were changed to T_1'. Well-being would diminish, and so on.

The responses to variables N and T as depicted in Fig. 3 may correspond roughly to what happens to salmonid communities in aquatic ecosystems with changes in loading by nutrients (N) such as phosphates and nitrates, or with thermal loading (T). Whether one or both types of loading are "good" or "bad" depends very much on the condition of the ecosystem prior to such loading.

The approach sketched above, and elaborated further by Regier and Henderson (1973), is analogous to that used by physiological ecologists to describe whole-organism responses to such factors as temperature, oxygen concentration, pollutant concentrations, etc.

One of the implications of the community model is that the responses listed in Table 2, i.e. those usually associated with the concept of "ecological succession," refer only to the partial set of recovery processes where increase in well-being follows relaxation of a "stress." Clearly a more complete characterization of community responses to important whole-ecosystem variables must be achieved before stress responses will be predictable to a useful degree of precision.

The question of what are the ecological characteristics of a fish community in a relatively unstressed state has seldom been addressed by fisheries researchers. Any angler who has fished normal, naturally unstressed lakes in remote wilderness knows some of the characteristics of a mature lake community: a substantial fraction of the biomass is fish, and a large proportion of the fish biomass occurs in the form of large, old members of long-lived species. Yet, many biologists seem to regard this situation as atypical or unnatural. Limnologists, particularly, appear to assume that the Eltonian biomass pyramid, with a broad base for lower trophic levels and a narrow peak for fish in general, is natural for an unstressed system. This is not the case. Though careful, comprehensive documentation is not yet available, many pieces of information point to the conclusion that where the Eltonian mass pyramid takes its "typical textbook" form, the fish community as such is under quite severe stress. Of course, with respect to energy flow, the pyramid has to take the usual form.

Our inferences, mentioned in the previous section, that all three major stresses in Lake Erie cooperatively drove the fish community from large (and long-lived) benthic forms to small (and short-lived) pelagic forms, is consistent with the above points. Many other observations and inferences of more limited scope are consistent with these proposals.

Conclusions

The main steps in elaborating a theory useful for managing medium-sized and/or complex fisheries might be as follows:

1. Develop a complementary set, with some redundancy, of variables that measure whole-ecosystem characteristics (see Henderson et al. 1973; Regier and Henderson 1973).
2. Develop a taxonomy of natural and cultural stresses as they influence the fish community.
3. Characterize conceptually and quantitatively the mature stages of ecological succession of a fish community in unstressed ecosystems typical of their geographical regions (Johnson 1972; Regier 1972).
4. Model and measure the effects of different natural and cultural factors or "stresses" acting separately and jointly on typical fish communities, and the consequence to species and to amounts of fish yields. Relational (correlation, regression) models would first be developed which would serve as tentative theory already useful for management. The tentative theory would in turn be the source of hypotheses to be tested by dynamic modelling and more conventional reductionist analyses. The results of such work should provide models and estimates at the scale of resolution and degree of accuracy useful for general decision making with those fisheries for which we now have no effective objective methods. I am confident that there would be scope for refining such whole-system models further to provide for effective subcomponent management.
5. In that the approach takes different classes of natural and cultural stresses into account explicitly, it should be particularly useful in an interdisciplinary multistage decision process.

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Assessing Fishery Potentials of Lakes and Reservoirs[1]

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Timeliness in estimating fishery potentials seems more important than precision, at least in the earlier periods of development of specific fisheries. Comparative studies of several sets of lakes, particularly of those supporting developing fisheries in Africa, suggest that potential yield may be related to several simple indices of production. The morphoedaphic index, derived from measures of total dissolved solids and the mean depth, has provided the simplest and most general approach to the problem of initial estimates of potential yield in lakes and reservoirs. Other methods of relating yield to nutrient concentration and primary production reinforce the concept of the dependence of potential yield on lake productivity. During the developing phase of a fishery more direct methods of estimating potential yield, through estimates of the production of the extant stocks, are also being used with some success. These have been adapted from fishery models developed for single stocks. In keeping with the need for rapid assessments during development, the simplest models have been emphasized. An equivalence between production and the product of biomass and mortality rate, along with the assumption that from 30 to 50% of the production of a stock is potentially harvestable, appears particularly useful. The problem of additivity of the potential yields of individual stocks seems relatively unimportant in first-order estimates, though the question of interactions is being examined, particularly in Lake Tanganyika. Programs of monitoring relative abundance of stocks over time have also been useful, both in indicating the approach of actual yield to potential yield and, after "calibration" against actual yields, as indices of stock and total biomasses.

Dans l'estimation des potentiels halieutiques, il importe plus semble-t-il de recueillir les données nécessaires en temps voulu que d'obtenir des données précises, du moins à un stade initial de développement pour certaines pêcheries. Des études comparatives effectuées sur plusieurs séries de lacs, notamment les lacs africains dont les pêcheries sont en voie de développement, laissent à penser que le rendement potentiel peut être relié à plusieurs indices simples de production. L'indice morpho-édaphique, calculé en mesurant les solides totaux dissous et la profondeur moyenne, constitue le moyen le plus simple et le plus général de procéder à une estimation initiale du rendement potentiel des lacs naturels et artificiels. D'autres méthodes consistant à établir une corrélation entre le rendement et la concentration de nutriments, ainsi que la production primaire, confirment la notion de dépendance du rendement potentiel à l'égard de la productivité du lac. Au cours du stade initial de développement des pêcheries, on utilise également avec un certain succès des méthodes plus directes d'estimation du rendement potentiel, consistant à estimer la production des stocks existants. Ces méthodes s'inspirent de modèles halieutiques mis au point pour des stocks isolés. On a souligné l'importance qu'il y avait à appliquer les modèles les plus simples, étant donné la nécessité de procéder à une évaluation rapide pendant les premières étapes du développement. L'établissement d'une équivalence entre la production et le produit de la biomasse et du taux de mortalité, ainsi que l'hypothèse selon laquelle 30 à 50% de la production d'un stock sont potentiellement exploitables, semblent particulièrement utiles. On ne pense pas qu'il importe, dans les premières estimations, d'envisager la possibilité d'additionner les rendements potentiels de stocks individuels, bien que la question des interactions ait été examinée, notam-

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

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ment sur le lac Tanganyika. Les programmes de surveillance ayant pour but de contrôler l'évolution quantitative des stocks ont également été utiles pour comparer les rendements réels aux rendements potentiels et pour fournir ensuite des indices sur les stocks et les biomasses totales.

La oportunidad de estimar los potenciales de pesca parece más importante que la precisión, por lo menos en las primeras fases de la explotación de determinadas pesquerías. Los estudios comparativos de diversos grupos de lagos, en especial aquellos en los que se haga la pesca en Africa, indican que el rendimiento potencial está relacionado con diversos índices simples de producción. El índice morfoedáfico, obtenido de las medidas de sólidos disueltos totalmente y la media de profundidad, ha proporcionado el método más simple y más generalizado para abordar el problema de las estimaciones iniciales de los rendimientos potenciales de lagos y estanques. Otros métodos para relacionar los rendimientos con la concentración de nutrientes y la producción primaria refuerzan el concepto de la dependencia del rendimiento potencial de la productividad del lago. Durante la fase de expansión de una pesquería pueden también emplearse, con algún exito, métodos más directos para calcular el rendimiento potencial mediante estimaciones de la producción de las poblaciones existentes. Estos métodos se han adaptado de acuerdo con los modelos de pesquerías formulados para poblaciones únicas. Debido a la necesidad existente de contar con evaluaciones rápidas durante el proceso de desarrollo se han destacado los modelos más simples. Una equivalencia entre la producción y el producto de la biomasa por el índice de mortalidad, junto con el supuesto de que de un 30 a un 50% de la producción de una población es potencialmente explotable, constituye un dato especialmente útil. El problema de que se puedan añadir los rendimientos potenciales de determinadas poblaciones parece tener relativamente poca importancia en las estimaciones de primer orden, aunque se está examinado la cuestión de las interacciones, en especial, en el lago Tanganyika. Los programas para observar la abundancia relativa de poblaciones durante tiempos determinados han sido también útiles y han servido para indicar el sistema a seguir para pasar del rendimiento real al potencial y después la "calibración" con los rendimientos reales, como índices de población y biomasas totales.

THE potential level of yield of a fishery is not a meaningful concept unless the contextual constraints are understood or made explicit. In this paper emphasis is placed on setting valid targets for development to assist in planning the appropriate scale of investment in research, gear, and market facilities. Furthermore, while various methods of augmenting the basic productivity of small bodies of fresh water are now in practical use, the larger lakes and reservoirs that comprise most of our freshwater resources, on an area basis, remain beyond the range of practical manipulation of basic productivity. Hence, "potential yield" in the present context is regarded as a prediction of the probable maximal level of yield that will be attained in a specific self-renewing resource, given a rate of development intended to reach this maximum in a relatively short period of time. The prediction is made, in other words, in the immediate technological climate.

The problem is not as difficult as it might seem. The development of a fishery may be divided into three stages: (1) unexploited: fishing activity too small to significantly affect the stocks, increase in yield is a simple linear function of increase in fishing units; (2) moderate: fishing activity sufficient to produce observable changes in the size or age structure of the stocks, increase in yield is a function of both fishing units and current total yield; and (3) intense: fishing activity a possible threat to recruitment of the stocks, total yield maximal or even decreasing with increase in fishing units. In the last stage, development objectives must necessarily shift to maintaining the maximal yield and to improving efficiency rather than increasing catches.

Gulland (in FAO 1970) has emphasized that, at the first stage above, only approximate estimates of the "limiting" yield are needed to make the practical decisions of development planning and implementation. Order-of-magnitude estimates (factor of 10) may be sufficient, while factor-of-two estimates are likely to be of greater precision than the precision inherent in predicting the economic, political, and social consequences of the contemplated development. At the second stage, the potential limits may begin to be evident from the fishing activity itself. Advice from the biologists is needed to determine if and when regulatory measures must be implemented. It is only in the third stage that details become critical. Small changes in regulations or technology significantly affect profits and hence further development. Potential yield, in the sense above, is clearly expressed in actual yield in this third stage.

There are obvious advantages in anticipating the development sequence, as fishery research often lags development so much that management of intense fisheries is generally aimed at restoring rather than maintaining the "potential" yield. This argues for higher precision at each stage. Practically, however, the development process itself provides much of the data needed to refine estimates, not only of the biological condition of the stocks but also of the economic factors as well. Various methods of estimating potential yield and related quantities associated with the first two stages of fishery development will be reviewed here, emphasizing methods which combine validity and rapid results, even if considerable precision is sacrificed.

Methods in Use to Develop Freshwater Fisheries

Estimates from Catch and Effort Data — the Problem of Interacting Stocks

Methods of assessing the status of individual stocks from catch and effort data need not be reviewed here. During the earlier stages of development of freshwater fisheries, individual stocks are rarely singled out as development targets. Maximal yield of a stock may not coincide with the maximum that may be obtainable from that body of water. An important aspect of the problem of estimating potential harvest is to determine the extent to which such estimates depend on the combination of stocks present or which might be introduced. Evidence from the studies of the African inland fisheries suggests that potential yield is not particularly sensitive to stock composition. However, these fisheries, in some contrast to temperate fisheries, are based on quite diverse fish communities. Some preliminary results from a study of catch and effort data of a developing pelagic fishery in Lake Tanganyika, a somewhat simplified tropical community, suggest why this may be so (Coulter 1970).

Catch per unit of effort, either from commercial or experimental statistics, may be taken as a measure of relative abundance, comparable over time for a particular stock. Simultaneous records of the changes in the relative abundance of several stocks should, if they are nonconstant, suggest whether interactions are apparent, even if the causal processes are not to be inferred from such data alone.

In Lake Tanganyika the most important species in the catches are the two small clupeids *Limnothrissa miodon* and *Stolothrissa tanganyikae*. The total catches for the whole of Lake Tanganyika have been recently estimated at about 70,000 metric tons per year or about 22 kg/ha (Welcomme 1972). More than half the catch is composed of these two clupeids. As this lake is large and exceptionally deep, the catch per unit area seems rather high and, it might be supposed, near the upper limit. Nevertheless, the abundance of the clupeids, while fluctuating markedly in 4- or 5-year "cycles," appears to be rising somewhat in spite of increasing fishing effort. In contrast, the large predators comprising three similar endemic species of the genus *Lates*, once abundant in the catches, appear to have diminished markedly in abundance, at a time coincident with the abrupt rise in the ring-net and lamp fishery for the clupeids. Indeed, large numbers of these predators were initially harvested along with the clupeids. With the decrease in the abundance of *Lates* spp. another endemic predator of smaller size and presumably shorter life-history, *Luciolates stappersii*, increased in abundance markedly and became important as a subsidiary element of the clupeid fishery. These changes are shown in Fig. 1 for the 15 years for which records were available in the Burundi sector of the lake.

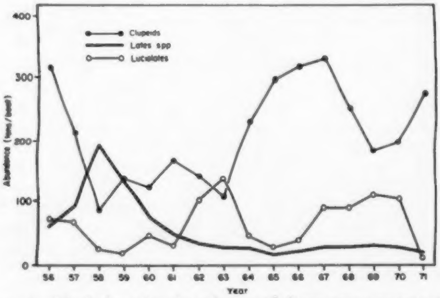

FIG. 1 Variations in abundance of three components of catches in the Burundi sector of Lake Tanganyika, as estimated from landings of the industrial fishery. The fishery started with four boats in 1956, increasing to 12 in 1958–60, remained at 8–10 boats from 1961 through 1968, then rose steadily to 15 in 1971. The clupeids were also fished by traditional methods (at constant levels 1956–1971) and by a rapidly expanding catamaran fishery (1969 onwards).

Regression studies suggest that nearly 80% of the variance in the clupeid abundance can be accounted for by the variance in the two groups, *Lates spp.* and *Luciolates*, while changes in fishing effort are not significantly correlated with the clupeid abundance. The behavior of this fishery, and another at the Zambian end of the lake of more recent origin, seems consistent with the following hypotheses:

(1) The abundance of the *Lates* was markedly reduced by the purse seine fishery. Conventional single-stock analysis suggests a threefold increase in total mortality between the first and second 5-year periods.

(2) The total mortality of the clupeids is primarily a function of predator abundance, the two predator types being roughly equivalent in the magnitude of their effects. Assuming that the ring-net fishery is similarly efficient in capturing predators and clupeids (equal catchability coefficients), the large difference in expected natural mortality rates of the relatively long-lived *Lates* and the short-lived (one-year) clupeids would account for the insignificance of the current fishing effort in controlling clupeid abundance.

(3) With the decrease in the abundance of *Lates*, the alternative predator *Luciolates*, assumed to be shorter lived, has replaced *Lates* as the primary consumer of clupeid production. While it too is heavily fished, the effect of the fishery is small relative to *Lates* and effectively hidden by response to the increased food supply, or perhaps to a reduction in *Lates* predation on young *Luciolates*.

(4) Total yield, the sum of the catches of the above three categories, is primarily a function of the food available to the clupeids. Increases in clupeid abundance are compensated by decreases in predator abundance and vice versa. The high turnover rate of the clupeids relative to the predators provides the theoretical requirement that the production of prey be higher than that of the predators, while prey biomass and predator biomass remain nearly equal. To a first approximation, the distribution of yield among the groups remains a function of relative biomass rather than of relative production.

Even if the above hypotheses prove applicable to the Tanganyika fishery, they may not be general. They are, however, remarkably consistent with the predator – prey model of Larkin (1966). It may be noted that the individual equations used by Larkin are identical in form with the Schaefer model if units of fishing effort are interchanged with units of biomass of interacting species. Such models may provide a framework for closer analysis of the problem posed. The approach is nearly identical to that taken by Schaefer (1970) in correcting the Peruvian anchoveta model for predation by birds. For want of suitable extensions of the fitting procedures, he estimated the predation coefficient from the food requirements of the birds.

EXPLORATORY SURVEY – THE GULLAND MODEL

A simple model of the relation of potential yield to "virgin" biomass was proposed by Gulland (1970a), and is particularly appropriate at the first stage of a developing fishery. Given a stock that is unexploited, it is sometimes possible to estimate the ichthyomass of that stock, B_0, by exploratory fishing with methods that provide sample estimates of density of the stock and the area of fishable grounds. If an estimate of the natural mortality rate, M, is available, then the expected potential yield, Y_e, is given by:

$$Y_e = x.M.B_0 \tag{1}$$

where x is a factor which probably lies between 0.3 and 0.5.

Inasmuch as the annual production of this stock is approximated by $M.B_0$ (Allen 1971; Paloheimo and Dickie 1970), the above is simply a statement that the fishery may expect to divert from one-third to one-half of the total annual production of the virgin stock to yield. Clearly, it is implicit in the method that full exploitation does not alter the production of the stock to any major degree. Gulland discusses the factors that lead to a choice of the coefficient x (the relation of the growth and mortality rates, and the permissible age at recruitment), given that M under exploitation is the same as M under virgin conditions.

An example of an attempt to use this approach is given by work in Lake Victoria in East Africa. It was known that inshore stocks were being heavily exploited, but suspected that large mixed stocks of *Haplochromis* existed offshore, which might be exploited by trawling. A program of exploratory trawling was carried out, based on over 1200 hauls distributed over the whole of Lake Victoria. Analysis of variation in catches showed a distinct distributional pattern by depth of the major species in the lake. The *Haplochromis* sp. complex was found to be eurybathic and constituted most of the total biomass of demersal species, which was 100 kg/ha. Assuming $x = 0.4$ and $M = 0.8$ the potential yield of *Haplochromis* was estimated at 30 kg/ha or 200,000 metric tons/year, as compared with the present inshore harvest of about 100,000 tons (Welcomme 1972). While demographic and nutritional conditions in East Africa justify the need for exploitation of this almost virgin *Haplochromis* resource, the potential success of a developing trawl fishery is restricted by several biological, sociological, and economic considerations. The preliminary estimate was useful in revealing the possibility of developing the fishery within these constraints. Whether the actual potential is closer to 100,000 or 400,000 tons is not of immediate significance.

GILLNET MONITORING FOR YIELD ESTIMATION

Gillnet monitoring of fish populations is an established method of estimating standing crops of fishes and proportionate numbers of the various species (e.g. Moyle 1950). Unfortunately, the complications introduced by gear selectivity (Regier and Robson 1966) and variations in fish vulnerability to the gear because of behavior differences (Hunter and Wisby 1964) often discourage the fish manager from doing other than compiling endless catch-per-unit of effort records, which hopefully will bear some relation to the actual standing crop or harvest of an extant commercial fishery.

Volta Lake, Ghana — Gillnet monitoring was employed for fish stock assessment purposes on Volta Lake, Ghana. The principal assessment gear was standardized gillnets of various mesh sizes fished systematically on eight zones of the lake at 3- or 4-month intervals. Concomitantly, yield estimates for a large commercial fishery were made at 3-month intervals. About 80% of the yield by weight was taken in gillnets, the remainder in other gear. A time-series plot of catch-per-unit effort of sampling gillnets and actual yield to all commercial gear for 1970 and part of 1971 agreed closely (Fig. 2). It was apparent that fluctuations in the commercial yield, not only on an annual basis but also quarterly, could be predicted from catch-per-unit effort of the monitoring nets. Quarterly predictions could be especially useful in a fishery where cold storage, transportation, and marketing facilities are still in the development stage. On Volta Lake predictions could initially be made only for the period in which the catch was taken. Even here, some benefit accrued to the fishery manager in that gillnet monitoring data were immediately available, while accumulation of all harvest records induced substantial time lag due to the logistic difficulty of obtaining complete catch records (or an adequate sample) from a large lake with many points of access. Once stabilization is achieved on a reservoir, however, it is expected that yield predictions may be made at least one-quarter in advance of the stock assessment. Variations in quarterly yield are often due to behavior differences such as spawning migrations which concentrate fish, thereby making a species seasonally more vulnerable to the gear. Initial prediction of commercial yield from gillnet monitoring on Volta Lake was made with a minimum of data, on the assumption that under a constancy of effort yield would bear a linear relation to catch-per-unit of effort of the monitoring gear (Fig. 3).

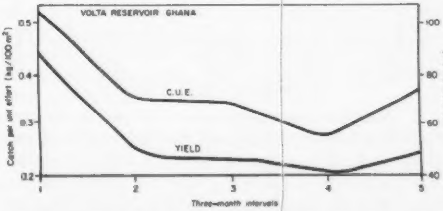

FIG. 2 Time series plot of catch per unit of effort for monitoring gillnets and estimated harvest by the commercial fishery at Volta Reservoir, Ghana.

Kainji Lake, Nigeria — A similar program of monitoring was used at Kainji Lake, differing in the use of a smaller range of mesh sizes. A corresponding program of yield estimation was initiated 1.5 years later, 2 years after the lake had reached its full level. Filling of this lake required only 3 months from closure of the dam.

While it was not possible at the time to estimate yield from data obtained with the gillnets, they made it clear that the total yield would diminish quickly after an initial

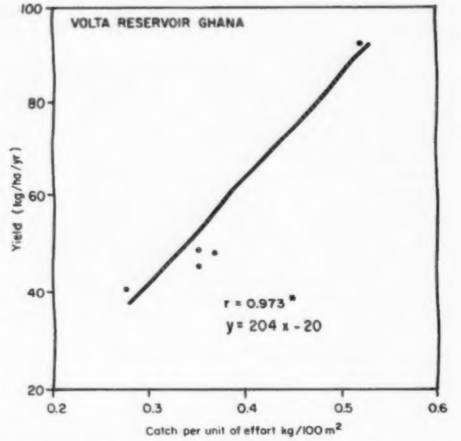

FIG. 3 Relation between estimated harvest by the commercial fishery and catch per unit of effort by gillnets used to monitor standing crops of fishes for Volta Reservoir, Ghana. Each point represents a mean value of a 3-month period. The regression line was fitted by the least squares method.

peak, owing to decline in *Citharinus* species. These species accounted for a large portion of the sample catches at the time of the peak in late 1969. Subsequently, results of yield surveys (Bazigos 1972) indicated a total yield in late 1970 and early 1971 of 216 kg/ha.yr, comprised of nearly 80% *Citharinus* spp. At the time of the 1972 survey, this yield had dropped to about 70 kg/ha per year.

In contrast to the Volta situation, the density of fishermen was high at Kainji. The apparent lag of 1 year between peak abundance as indicated by the gillnet monitoring program and the peak in yield can readily be explained by differences in mesh sizes used: 2–7 inch (51–178 mm) stretched mesh in the monitoring program, and 6–8 inch (154–203mm) stretched mesh in the fishery. During the period of rapid expansion in the fishery, the monitoring program, in effect, estimated the stock available in the following year. With the decline in *Citharinus*, nets of smaller mesh began to be used by the fishermen. The results suggest that monitoring by individual mesh size could be an effective tool for assisting the fishermen in the selection of suitable gear.

In both lakes the monitoring programs were rather intensive. Estimates were obtained 3 to 4 times each year, fishing with more than 10 gangs of nets distributed over as many locations in the lakes at each round. This intensive sampling may explain the success of these programs in spite of a priori reservations regarding reliability of gillnets as a sampling tool. The fact that the fishery itself was primarily based on gillnetting may also partly explain the close relationships found between the sampling programs and the yield. Bagenal (1972a,b) has reported that in Lake Windemere the variance of mean catches of both traps and gillnets diminished rapidly with increasing replication, up to about 6 replicates.

ESTIMATES OF PRODUCTION BY SPOT-POISONING

Recently many workers have used fish poisons to sample blocked coves or unenclosed sample areas. Although the advantage of high efficiency of capture is partially offset by the difficulty of selecting both suitable and representative sites in the larger lakes, the method is attractive for obtaining direct estimates of standing stock. If the age structures of the various stocks are simultaneously estimated, mortality and production may also be estimated. The latter provides a seemingly direct approach to estimates of potential yield.

An attempt to follow the above scheme was made at Lake Kariba, Zambia (Balón 1972). Ten cove and shore samples were obtained over a period of about 3 years. Echo surveys suggested that most of the fish were to be found in water less than 20m in depth, about 60% of the lake area. The locations to be sampled were selected to represent this shallower portion of the lake. The total production of the 20 most common species was calculated, and the production of the harvestable stock (Balón's "available yield") was taken as a base for calculating potential yield.

Assuming that 40% of the production is potentially harvestable (factor *x* in equation 1, above), the potential yield was estimated at between 50 and 75 kg/ha, depending on how the estimate is distributed over the lake as a whole. Actual catches are estimated at about 10 kg/ha.

TROPHODYNAMIC AND ENERGY FLOW METHODS OF ESTIMATING POTENTIAL PRODUCTION

Several workers have attempted to estimate potential production and yield of particular fisheries and also world totals, using food-chain theory and models (Gulland 1970b). While the results have generally been unsatisfactory in precision, there is increasing evidence that the nutrient concentration and the level of primary production are the significant factors in determining the community production of higher trophic levels. The correlations found between the morphoedaphic index and yield, discussed in the next two sections provide one such line of evidence. Some further examples are briefly discussed here to suggest alternative approaches.

Nitrogen in the trophic chain — In reviewing studies of effects of water quality on fish yields in fish ponds and reservoirs by Czechoslovakian workers, Hrbaček (1969) noted that good correlations had been found between Kjeldahl nitrogen concentration in the water and in zooplankton (expressed relative to the volume of water from which the zooplankton was taken), and between Kjeldahl nitrogen and fish yield per hectare. He noted particularly that correlations of individual observations were poor, but that mean values of nitrogen concentration for particular water bodies gave useful results. This remark anticipates the comments of Brockson et al. (1970) that trophic level dependencies are better expressed in annual means, while point observations are more likely to trace out the lags that seem characteristic of predator – prey relations. The water bodies taken for comparison included fishponds, backwaters, and two reservoirs (Klicava and Slapy). The correlation between nitrogen in the water and fish (carp) yield was less clear than between nitrogen and zooplankton, but removing cases with large stocks of unharvestable rough fish greatly improved the correlation.

The use of nitrogen balance, rather than energy balance, in studies of growth efficiency has become well known through the work of Gerking and his colleagues. Further, the well known role of nitrogen in eutrophication argues for wider exploration of nitrate measurements in predicting fish yields.

Primary production and fish production in tropical lakes — Primary production was estimated for a number of East African lakes by Talling (1965). Although these estimates were derived from relatively few samples in each lake, it seems likely that the tropical lakes do not exhibit as great seasonal variability as those of temperate regions. Where seasonal variability is observed, it seems generally to be related to turbidity rather than temperature or incoming radiation (Talling 1965, O. O. Karlman personal communication). Richardson (1968), working from Talling's data, noted a close correlation between total dissolved solids and gross primary production on an area basis. Aberrant values seemed to occur for Lake George (higher production than expected) and Lake Rukwa (lower). The production in Lake Rukwa seemed to be limited by high turbidity, and the expression of production as the maximum production reached per unit volume, in a vertical water column, gave a more consistent correlation for all lakes in the series. Talling's data also appear to yield a fair correlation with the morphoedaphic index (total dissolved solids/mean depth) when expressed in log – log form (Fig. 4). The slope of the regression is small, however, and hence the regression must be regarded as dubious.

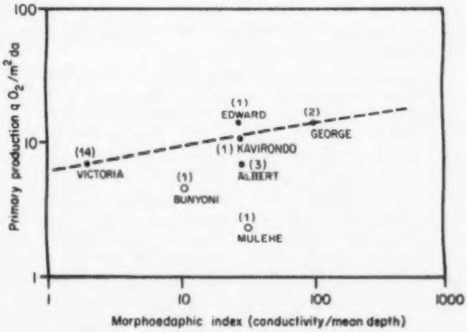

FIG. 4 Relation between primary production and morphoedaphic index for six East African lakes, data from Talling (1965) and Talling and Talling (1965). Lakes Bunyoni and Mulehi lie at higher altitudes and have significantly lower water temperatures. The other lakes are those included by Regier et al. (1971) in relating fish yield to the index; Kavirondo (Nyanza) Gulf and Lake Victoria proper are separated. Numbers in parentheses are the number of experiments upon which the mean primary production was calculated.

To examine the overall relation between primary production and fish production in tropical waters, a gross relation was explored (Fig. 5) for use in bracketing production values for Kainji Lake, Nigeria. Here the reported range of values of primary production given by Talling has been compared with ranges of fish production on a trophic-level scale, all values being converted to dry-weight equivalent. A particular fish fauna was assigned to a trophic level by assuming that three levels could be distinguished: herbivorous, microphagous, and predacious, and that the average trophic status of the fauna was determined arithmetically by the relative proportions of the total biomass in the three categories. It was further assumed that yield or catch was equivalent to one trophic level above the average trophic level of the stock. The resulting diagrammatic model suggests that one might expect to find increasing ranges of variability in production in moving to higher and higher trophic levels. Unfortunately no comparable data could be found to indicate the range of production of the zooplankton or converter level.

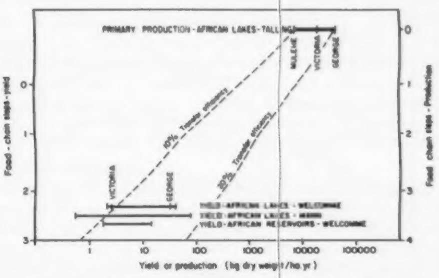

FIG. 5 Trophodynamic model of relation between primary production and fish yield (African lakes) based on classical food-chain concepts. Yield from production at a given trophic level is considered equal to production at the next higher trophic level. Data from Talling (1965), Mann (1965), and Welcomme (1972).

Comparing the slopes of the regressions of primary production and of fish yield on the morphoedaphic index (see the next Section), one might infer that the fish yield increased as a power function of primary production. This would fit well into the above model. An apparently reasonable interpretation of both is that most trophic transfer efficiencies may tend to be low in waters of low primary productivity and high in waters of high primary productivity.

THE MORPHOEDAPHIC INDEX AND OTHER ABIOTIC VARIABLES

The morphoedaphic index (MEI) is an empirically derived formula that was first described as a convenient method of rapidly calculating potential fish yield for unexploited north-temperate lakes (Ryder 1965). Since its inception, the constraints on the use of the MEI have been relaxed, and it has been applied successfully to sets of lakes other than those for which it was modelled originally (Fig. 6). Recent evaluation of the MEI has resulted in its application within several different climatic systems, or lake sets in which the individual lakes possess

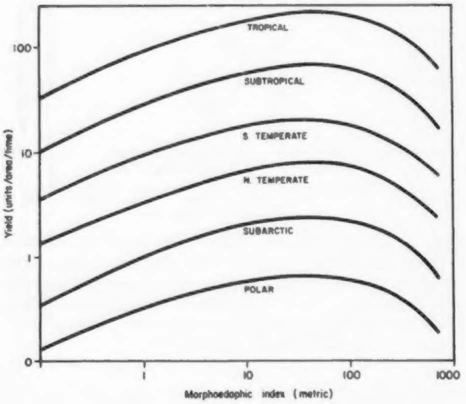

FIG. 6 Predicted yield curves for six sets of natural lakes representing six of the world's climatic zones. At any constant level of the morphoedaphic index, yield may depend primarily on climatic effects (e.g. length of growing season).

a number of limnological conditions in common (e.g. all belong to the carbonate – bicarbonate group of inland waters). At present yield – MEI relations have been described, or exist in unpublished manuscripts, for north-temperate lakes of North America, moderately to heavily exploited and lightly exploited (Ryder 1965), north-temperate oligotrophic lakes (Ryder 1972), north-temperate lakes of Finland (unpublished data), reservoirs in the United States (Jenkins 1967), large tropical lakes of Africa (Regier et al. 1971), and African reservoirs (unpublished data). Additional material pertaining to MEI – yield estimates may be found in Jenkins (1970) and Jenkins and Morais (1971).

Description — The MEI is composed of two limnological variables or their measurable correlates. Total dissolved solids (mg/liter) divided by mean depth (meters) provides a metric expression of the MEI. In actual computation of the index any correlate of total dissolved solids (TDS) for which a conversion factor is available may be used as a substitute for that variable. Conductivity and total alkalinity are the two correlates of TDS most commonly substituted for the latter. Conversion factors for these two correlates of TDS may be found in Hutchinson (1957, p. 558) and Ryder (1964).

Mean depth has no direct correlates useful for substitution in the MEI expression, but may be calculated as a standard proportion of maximum depth in lakes with a regular bottom configuration (Neumann 1959). Normally, mean depth is obtained by dividing the volume of a lake by its area when such data are available. A reasonable approximation of mean depth may be obtained by averaging equidistant depth readings for a minimum number of lake sounding transects.

Significance — The MEI concept is superficially one of simplicity, such that it is overlooked frequently as impractical for use in estimating fish yield. While use of the index provides neither a panacea nor final solution for all yield-estimate problems, it does afford a useful first approximation which has greater value for any individual lake if the set of lakes to which it belongs has been described previously. The inherent significance of TDS and mean depth within the context of the MEI is not precisely known. It is suspected, however, that TDS is generally proportional to one of its component ions (limiting or indicative of biological production), such as phosphorus, nitrogen, or carbon. The constant proportionality of certain ionic components of carbonate–bicarbonate lakes have been documented (Rodhe 1949; Hutchinson 1958; and many others). Whether TDS is a prerequisite to, or a consequence of, high production is irrelevant within the context of yield estimation. TDS does, however, represent an average edaphic condition for any watershed as it reflects, to a certain degree, geological characteristics of the watershed as modified by climatic effects such as rainfall. A high runoff into a lake following a heavy rainfall might be expected to influence nutrient levels (phosphorus, for example) proportionate to the stoichiometric relation among the various nutrients in the ionic spectrum. Total influx of TDS from various affluents into a lake in turn will reflect a mean value for the lake, provided that sufficient mixing takes place and that subsequent sampling is adequately stratified on a time and space basis. Ultimately, TDS probably bears a similar relation to nutrient loading (Vollenweider 1969) as standing crop of fishes bears to actual fish production.

The inherent value of mean depth as a yield estimator is somewhat obscure, yet in multiple regression treatment mean depth usually accounts for more of the yield variability than does TDS (Ryder 1965, Jenkins 1967). Rawson (1955) has stressed that mean depth is the most important morphometric feature of a lake. On inspection it may also represent other morphometric variables to varying degrees. In part it depicts the extent of the "euphotic-littoral" zone — that depth stratum of a lake which allows adequate light penetration for the growth of planktonic algae, and at the same time, is sufficiently shallow to provide attachment surfaces for sessile plants within the euphotic zone. Mean depth represents shore development and insulosity to a certain degree, although the relation is by no means close. It is an obvious correlate of area (Hayes 1957, fig.1) although this relation is a general one only and does not hold necessarily for individual lakes. And, of course, mean depth is directly correlated with volume when area is constant or inversely with area when volume is constant.

As in the case of high TDS (cause or effect), it is not known whether shallow lakes are productive or productive lakes are shallow. Often the same conditions that contribute to shallow lakes also contribute to relatively high productivity. Productive north-temperate lakes, for example, are more likely to be found in rich sedimentary deposits (Pleistocene), where depth is often restricted because of the looseness of the substrate. On the other hand, the most unproductive lakes are usually located on a firm igneous substrate that sustains great depths and U-shaped basins and simultaneously (because of its consistency) releases nutrients at a slow rate. Lakes with extremely high mean depths may serve as a "nutrient sink" in which seston settles to the bottom, removing nutrients from the system either temporarily (north-temperate dimictic lakes) or permanently, as in Lake Tanganyika, an African lake with meromictic characteristics (Beauchamp 1939).

Other abiotic variables — The list of abiotic variables that may be of assistance in predicting the potential fish yield of a lake is inexhaustible. Variables that are frequently measured include shore development, depth of the euphotic zone, turbidity, and transparency (both biotic and abiotic), various ions, meteorological variables such as precipitation, wind and sunlight, mean temperature of the trophogenic zone, dissolved oxygen in the hypolimnion, thermocline depth, and length of growing season (biotic and abiotic).

Specific abiotic variables may have significant effects on production in reservoirs while affecting natural lakes to a lesser or insignificant degree. Flushing rate, outlet depths, and water level fluctuations are three abiotic effects that are often considered important in reservoirs. Although these abiotic variables may affect fish production, they usually express only a minor part of the total variability except in special circumstances. High levels of inorganic turbidity in the form of colloidal clays, for example, may so inhibit light penetration and hence suppress photosynthesis that high nutrient levels and low mean depth (a generally favorable condition for fish production) may be completely obliterated by the negative effects of this factor. Three possible methods of coping with this problem within the use constraints of the MEI are: describe a subset of lakes in which high levels of inorganic turbidity approaches homogeneity or fluctuates within a predetermined range of low magnitude; include inorganic turbidity as a third independent variable in regressions of yield on MEI; or use knowledge of the existence of high inorganic turbidity to modify subjectively in the appropriate direction previous estimates of fish yield based solely on the MEI. The first option will prove to be the most useful ultimately, but will require data from a series of lakes subjected to high levels of inorganic turbidity. The requisites for satisfying the second option are not as rigorous. It would necessitate regression computation for a series of lakes in the same climatic set, preferably with a wide range of inorganic turbidities. The proportion of yield reduction attributed to inorganic turbidity could be separated then from that related directly to TDS and mean depth. The third option will lack precision but should provide a yield estimate of greater reliability than that obtained from the MEI alone in waters of extreme inorganic turbidity. Other abiotic variables of less importance may be handled in a similar manner.

Application Methods for Abiotic Variables

NATURAL LAKES

For a first approximation of yield by the MEI method a natural lake must meet the requirements of at least five basic criteria: 1) relatively homogeneous climatic conditions within the set; 2) all lakes in the set should be of the carbonate–bicarbonate series (or the sulphate series, etc), i.e. have approximate ionic homogeneity; 3) minimal variation in flushing rates among lakes of the set; 4) inorganic turbidity of the same order of magnitude for all lakes in the set; 5) moderate to intensive fishing effort. The last criterion is not essential where a lake complies with all other requirements and belongs to an existing set of lakes for which the MEI–yield relation has already been demonstrated.

Once it is established that a lake is a component of a predetermined set and its MEI has been calculated, potential yield may be predicted usually to within a factor of two by locating the position of the lake on the regression line for its set. More simply, yield is determined by solving the equation predetermined for any set of lakes. For example, when estimating potential yield for African lakes reference should be made to the sets of Regier et al. (1971).

A lake with a moderate to intensive fishery for which yield is known may not fit the predetermined regression for its set. In such a case it is useful to look for an anomalous limnological condition, or violation of the basic criteria for including a lake within any particular set. The anomaly may be either abiotic or biotic, and if sufficient lakes are found with similar conditions, a new set may be described.

RESERVOIRS

Estimating yields — Reservoirs may be treated in the same fashion as natural lakes, with certain additional considerations. Reservoirs are normally impounded streams, and phytoplankton is not an important primary producer in running waters. Stream energy flow stems primarily from attached algae, allochthonous materials and detritus (Hynes 1970), and reservoirs, at least in some parts of them, are subjected to modified food webs of both natural lakes and those of their parent streams. This factor, combined with the relatively large flushing rates of reservoirs, would necessitate the description of reservoir sets for each climatic zone.

New reservoirs (recently impounded) are subject to a different set of conditions and the MEI is not immediately applicable, although it probably represents potential yield adequately. For example, sufficient biotic stability is achieved in tropical reservoirs usually no sooner than 5 years after initial impoundment and may require as long as 15 years. Additionally, a time lag exists between the complete filling of the reservoirs and expansion of fish populations to fill all available habitat.

The rapid increase in nutrient level following filling of a lake is parallelled by increased fish production (after an appropriate time lag), with resulting higher yields. The Volta Reservoir in Ghana showed increasing yields subsequent to flooding which parallelled increased nutrient levels, in this case represented by total alkalinity (Fig.7). The lag between peak nutrient level and peak yield was 1 year. Fishing effort also increased over the same period, contributing to a larger total yield, but not accounting for increased yields on a unit-area basis. As both nutrient levels and mean depth were changing during flooding,

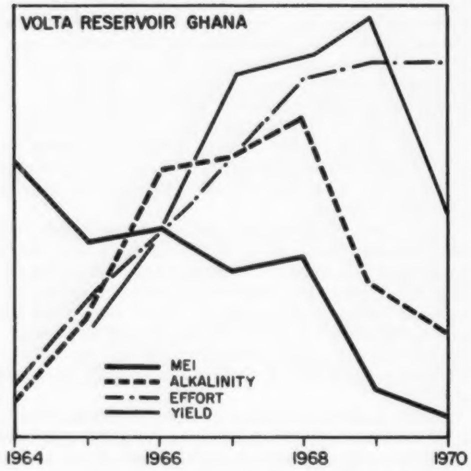

FIG. 7 Temporal changes during flooding in levels of alkalinity (mg/liter), fishing effort expressed as number of fishing canoes, yield (kg/ha), and the morphoedaphic index between the years 1964 (first flooding) and 1970 in the Volta Reservoir, Ghana. Ultimate water levels were reached in 1968.

with consequent changes in the MEI (Fig. 7), the latter variable would be useful only for estimating the potential instantaneous yield at any point in time. Once a reservoir is stabilized however, with only minor fluctuations in depth and nutrients, the MEI may be used as described for natural lakes. In Volta, the maximum water level was achieved about 1968 (Fig. 7); subsequently, nutrient levels declined and fish yield became correlated with both total alkalinity and the MEI, if the appropriate time lag was taken into account. Trends in yield followed most closely the alkalinity curve during the period of flooding. Reasonable yield predictions could have been made at any time following 1968 on abiotic factors alone as long as fishing effort was moderately intense and approached constancy. Predictions on this basis appear to be practical for at least 1 year in advance of the fishery.

Estimating peaks and troughs — Although it may be possible to assess changes in yield 1 year in advance on the basis of nutrient changes alone, estimating several years in advance at what yield the fishery might level off, or where it might peak, is desirable for management purposes.

Many abiotic and biotic variables fluctuate in unison during the filling of a reservoir. Area, volume, and mean depth increase during flooding. Various ionic components increase as represented by alkalinity. The number of fishermen increases as a reservoir becomes larger and actual fish yield on a per unit basis increases (Fig. 7). Once depth, volume, and area are stabilized some of these variables decrease, notably, nutrient levels and yield per unit of effort (Fig. 7). As these and other variables appear to fluctuate uniformly, and if we assume that they will continue to fluctuate in unison in the future, a completely mathematical approach may be taken to estimate at what level the yield will peak during filling, or more usefully, to what asymptotic level the yield will decline on stabilization. The Gompertz curve technique (Croxton et al. 1967) is admirably adapted for such situations, and has been successfully employed as additional proof of the level of yield stabilization for the Volta Reservoir (Bazigos 1971). It should be emphasized that this is strictly a mathematical approach for placing a second approximation on asymptotic yield for a reservoir, and is subject to error depending on the vagaries of biological variability.

Yield data for the Gompertz curve were grouped by 6-month intervals. An increasing ratio in the yield decline was observed when the harvests of consecutive intervals were compared. This ratio did not increase constantly by amount or percentage and consequently the criteria for use of the Gompertz curve technique were satisfied. An asymptotic yield value of 42.9 kg/ha was computed for the Volta Reservoir (Fig. 8) on the assumption that biotic and abiotic conditions will fluctuate relative to one another in the future.

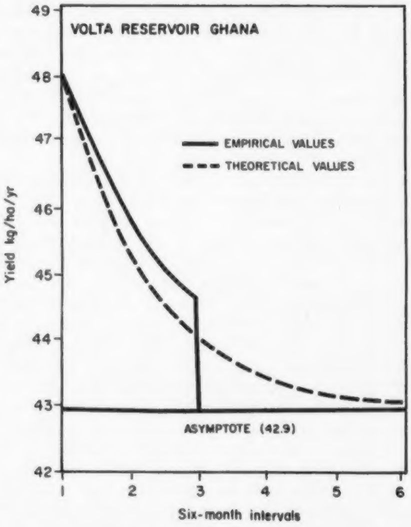

FIG. 8 Asymptotic level of yield computed from the Gompertz curve for the Volta Reservoir, Ghana, upon stabilization (after Bazigos 1971).

Acknowledgments

Many of the data on which this discussion was based were collected by fisheries workers of the countries mentioned and by personnel of the FAO/UNDP Lake Projects in these same countries. The contributions of these workers are gratefully acknowledged.

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Assessment of Unexploited Resources

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For a sound development of fisheries on the world's remaining unused resources an evaluation of the potentials is needed, both to encourage interest and to provide guidance for timely management. The type of information required is not limited to stock potentials but should include main features of fish biology, behavior, catchability, size, quality, etc.

The possible methods and sources of information are of two kinds: indirect and direct. Indirect methods make use of information on the oceanography and basic productivity of sea areas and of ecological relations. Examples are mapping of upwelling areas, charting of observations of basic productivity, and stomach content studies.

Direct methods base themselves on quantitative observations of any stage of the resource itself, thus including egg, larval, and postlarval surveys, exploratory fishing, acoustic surveys, aerial scouting, and observations from vessels engaged in other primary tasks. The advantages and limitations of these various methods and the conditions for their successful use are discussed and compared.

Si l'on veut procéder à la mise en valeur rationnelle des ressources halieutques mondiales non encore exploitées, il est nécessaire d'en évaluer le potentiel tant pour susciter de l'intérêt à leur égard que pour fournir des directives en vue de leur aménagement en temps voulu. Les renseignements dont on a besoin ne se limitent pas uniquement au potentiel des stocks, mais doivent inclure des données générales sur la biologie des poissons, leur comportement, la possibilité de capture, la dimension des poissons et leur qualité, etc.

Les méthodes et les sources de renseignements auxquelles ont peut avoir recours sont de deux sortes: indirectes et directes. Les méthodes indirectes utilisent des données sur l'océanographie et la productivité de base des zones maritimes et des relations écologiques. On peut citer comme exemple l'établissement de cartes pour les zones d'upwelling, la mise en graphique des observations relatives à la productivité de base, des études sur le contenu stomacal et autres données.

Les méthodes directes se fondent sur des observations quantitatives relevées à n'importe quel stade de l'évaluation des stocks, à savoir: enquêtes sur les oeufs et les stades larvaires et postlarvaires, pêche exploratoire, prospections acoustiques, reconnaissances aériennes et observations effectuées accessoirement à partir de navires dont la mission essentielle est diverse. L'auteur étudie et compare les avantages et les limites de ces différentes méthodes, ainsi que les conditions de leur réussite.

Para que tenga lugar un desenvolvimiento adecuado de la pesca de los recursos que aún quedan sin explotar en el mundo, es necesaria la evaluación de los potenciales con objeto de fomentar el interés y proporcionar una orientación para la reglamentación oportuna. El tipo de información que se necesita no está limitado a los potenciales de poblaciones, sino que también deberá incluir las principales características de la biología íctica, comportamiento, posibilidades de captura, talla del pez, calidad, etc.

Los métodos posibles y las fuentes de información son de dos clases: indirectos y directos. Los métodos indirectos se valen de la información sobre la oceanografía y la productividad básica de las zonas marítimas y de las relaciones ecológicas. Se mencionan los siguientes ejemplos: cartografía de zonas de afloramiento, tabulación de las observaciones de la productividad básica, estudios sobre el contenido del estómago y otros.

Los métodos directos se basan en las observaciones cuantitativas de toda fase del recurso mismo; e incluyen: huevos, estudio del estado larval y postlarval, pesca exploratoria, estudios acústicos, reconocimientos aéreos y observaciones desde barcos dedicados a otras tareas primarias. Se debaten y comparan las ventajas y limitaciones de estos diversos métodos y las condiciones para que puedan emplearse con éxito.

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

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THE more and more widespread problem of overexploitation of resources, with resulting waste of effort, low profitability, and resource depletion, has tended lately to draw the attention of the world fishing community away from the perhaps equally important problems of the underutilized resources of the world oceans. Estimates of the potential of such resources range upwards from yields corresponding to the present world catch. It should be emphasized that, in contrast to the position of nonrenewable resources such as oil and minerals, the failure to utilize living marine resources represents a complete and absolute waste of production.

A basic problem for an increased use of unexploited resources is the provision of reliable and detailed information on the resource. Such information is needed not only to encourage the start of new fishing enterprises, but also to guide their development along an economic and safe path. Far too often initially profitable fisheries, which have been left to develop freely, have in a short time changed into economically marginal undertakings because of overinvestment and an overestimated resource potential. The need for an early assessment of the resource is therefore twofold: to encourage interest in new fishing areas, and to provide guidance for early management.

For sound planning of fishery development the resource information required is not limited to the stock potential, but must include a wide range of additional observations and data on the fish stocks in question. These include the main features of life history, distribution, migrations, behavior, catchability, size, quality, and so on. While some methods of resource evaluation will provide such additional information, others will not, and this must be borne in mind when comparing and evaluating the various methods.

There are two approaches to the assessment of unused resources. The indirect methods are based on general information about the sea area and its main oceanographical characteristics and basic productivity. Comparison of such data with similar information from areas with developed fisheries may already provide a first rough evaluation. Studies of ecological relations, e.g. by means of food chains, stomach content samples, guano birds, etc., provide other means of indirect assessments. Direct methods, on the other hand, make use of any type of quantitative observation on the resource itself, including its reproductive stages. Thus they range from egg and larval studies to exploratory fishing, acoustic surveys, and aerial scouting.

Indirect Methods of Assessment

The production of exploitable resources of fish or other organisms in an area is based on the productivity at lower trophic levels: the primary production of plants, the secondary production mainly of zooplankton, which feeds on the plants, and the production of tertiary and eventually higher levels of fish. Most commercial fishes depend on secondary or higher levels for food. Primary production in the sea, which largely takes the form of unicellular algae, needs light and is limited to a surface layer of less than about 100-m depth. Another requirement is a supply of various nutrient salts. Conditions for primary production vary greatly in the oceans and are closely related to oceanographical processes that bring a supply of nutrient rich water up to the surface euphotic layers. At high latitudes this process is usually associated with convection brought about by seasonal cooling of the surface, or by mixing in frontal areas between different water masses. At lower latitudes upwelling is the most important oceanographical phenomenon related to productivity. Various methods can be used to estimate primary production. One may observe the in situ production from samples by measuring oxygen production or uptake of carbon. The latter method, which makes use of radioactive carbon (C_{14}), is now widely used and data are available from many parts of the oceans. The interpretation of such observations in terms of absolute production presents a number of problems, but the data are still of great value in a relative sense.

Oceanographical studies are widely used to assess the general productivity of regions, perhaps because the underlying data are more easily accessible, and large masses of oceanographical observations are available from nearly all parts of the oceans. Most of the world's unexploited or underexploited resources are confined to lower latitudes, and here upwelling is the phenomenon of greatest interest for productivity. Cushing (1970) in a study of upwelling and fish production reviewed the dynamics of the various processes of upwelling and described and quantified the upwelling areas and their seasons. The most important are the coastal upwellings in the eastern boundary currents in the subtropical anticyclonic current systems north and south of the equator: i.e. the Peru and California upwellings in the Pacific, and the Benguela and Canary upwellings in the Atlantic. Conditions in the Indian Ocean are dependent on the monsoon. Here the upwelling off southwest Arabia is the dominant one, but it also occurs seasonally off Somalia and the Malabar coast. As pointed out by Cushing, the areas of high productivity associated with upwellings can be revealed indirectly on maps of deposits of phosphorus on the sea bottom, the world distribution of guano islands, and the distribution of the historical catch of sperm whales.

Information on the physical basis of productivity and on primary production itself is, of course, only of general indirect interest for evaluation of the fishery potential of an area. It has often been and should generally be used as a guide for forming a policy for fishery explorations. Information on the general productivity of an area can also be used in addition to and supplementary to other available data.

Zooplankton productivity is one step closer to fish, but the problems of measuring and estimating total zooplankton production are generally greater than for primary production. Total zooplankton biomass may be assessed from samples, but the need for coverage in time and space is often considerable and involves costly vessel time.

Ecological relations can be used to provide rough estimates of the potential of a resource or as a guide to further studies. For example, the stomach contents of carnivorous fish or other marine animals may provide indications of the presence and abundance of fish resources. The abundance of the predators themselves will in such cases be an important piece of information. An interesting example is the assessment of small pelagic fish from the abundance of guano birds and their production of guano.

An important approach to indirect assessments is the comparison of the extent of sea areas thought to be of equal or known productivity. Such estimates should be based on information on species distribution and the oceanographical and biological characteristics of the relevant sea areas, data which are usually more readily available than more direct data on fish abundance. This method is perhaps in practice limited to adjacent areas where exploitation has already started on part of the grounds.

Direct Methods

EGG AND LARVAL SURVEYS

Studies of the distribution of egg and larvae may make possible an assessment of fish stocks, and will provide important information on the life history, distribution, and concentrations of fish. An Advisory Committee on Marine Resources Research (ACMRR) Working Group recently reviewed the potentialities of egg and larval surveys in fisheries research (Anon 1971). For species in which these stages are planktonic there is the obvious advantage that this stage of the fish stock is concentrated in the upper layer of the sea where sampling with relatively simple gears is possible. There are, however, a number of prerequisites for the successful use of this method in detecting and assessing new resources. The problems of identifying the eggs and larvae must be solved. In the warm waters of the tropics and subtropics the growth of the eggs and larvae is rapid so that these passive stages of the fish's life are brief, and this poses special sampling problems with regard to coverage in both time and space. For an unselective catch of postlarvae more sophisticated sampling gear is needed. At low latitudes the spawning of fish is often less restricted both in time and in space than in colder regions, and this increases the research effort needed. Generally speaking egg and larval surveys make relatively heavy demands on vessel time and also on expert time for processing. The sampling operation is on the other hand simple, and the investigations can be made with almost any type of vessel. The costs of such surveys will still be relatively high and a careful comparison should always be made with other survey methods directed towards the fish stocks themselves. Sampling for eggs and larvae can often be incorporated into other survey programs without much additional cost and effort, particularly into more fundamental oceanographical investigations. The design and coverage of such surveys will, however, seldom meet the requirements to a proper egg and larval survey, and the collected material will therefore only be of limited value for resource assessments. Useful indications may still emerge from such more incidental programs and they are recommended on this basis.

Egg and larval sampling may also provide indirect information on species composition and identification, which may be of importance in acoustic and exploratory surveys.

An FAO manual on the use of egg and larval surveys for resource evaluation is under preparation by an ACMRR group.

0-GROUP SURVEYS

The planktonic or semiplanktonic stages of many fish species may last considerably beyond the larval state, sometimes for a large part of the first year of life (0 year). Such stages offer several advantages for surveying: concentration in upper water layers, less pronounced schooling behavior, relatively high catchability. These young stages are often associated with processes that distribute the fry from the spawning areas over the total feeding area of the species, the mechanisms being usually drift in a major ocean current. The geographical extent of the survey can in such cases be considerably less than the total area of distribution of the fish. 0-group surveys are based on high performance echosounders for locating the layers or concentrations in which the young fish are found, and on sampling with pelagic young fish trawls. The trawls must be designed, as far as possible, to catch the small fish stages unselectively.

0-group surveys are a new and in some respects more promising method than conventional egg and larval investigations. The survey effort will be less, particularly the temporal coverage, and the results may be more directly relevant to the fisheries, at least in the more developed stages of the latter because of the information on recruit abundance and stock fluctuation that may become available. A prerequisite for such surveys is a fairly complete understanding of the life history of the fish stock in question, and the method will therefore not be feasible in new and completely unknown areas.

EXPLORATORY FISHING SURVEYS

Alverson (1971) defines exploratory fishing as "a planned study by fishing gear of the fish resources inhabiting a defined area of the ocean." In reviewing the aims of such investigations he points out that these are to some extent different for the two parties principally interested: the scientist-administrators and the commercial industry. Whereas the scientific interest is more towards a general description of the resources and their potential on a long-term basis, the industry will also and more immediately be interested in distributional and catching aspects, and the size and quality of the fish. Exploratory fishing is, of course, the "prospecting method" that will provide a maximum of the latter type of information, and will therefore always form an indispensable part of preinvestment studies for fisheries development, either alone or combined with other methods of resource evaluation.

The fact that this method is based on the simple and direct principle of trial fishing may perhaps account for the lack of systematic planning that so often has characterized exploratory fishing and resulted in incomplete and misleading conclusions. Careful planning is essential and should start with a clear definition of aims in terms of area and types of resources. All available information on the sea area and its oceanographical characteristics should be evaluated, as well as any available data on productivity at various levels.

Particular attention should be given to the choice of vessels and gear, which both technically and economically are the key elements in this kind of work. The distinction that is often made between trawlers and purse seiners, in most fishing fleets, is usually based on economy and tradition. The construction of, or conversion to, dual purpose vessels is fully feasible, the most important factors to consider being engine power and winch arrangements. A combination vessel for purse seine and midwater/bottom trawl is essential in surveys for most types of small pelagic fishes. In the choice of a vessel and its mode of operation it may be essential to keep in mind the distinction that can be made between exploration for resources and their availability in the area, and commercial simulation fishing. The requirements for the vessel, its hold capacity and economics of operation, will usually be more specific for simulation fishing. For exploration the principal requirement is that the vessel can fish with full-sized commercial gear, but it will usually be a waste of costly vessel time to land the catch or even bring the whole catch on board the vessel. Catches must be discarded after sampling and quantitative estimates have been made.

The distribution in time and space of the total survey effort is an essential part of the planning. A completely random distribution of sampling points is uneconomic and impracticable. For bottom trawl surveys and for other resources for which some form of relative distribution index can be established, the method of stratified random sampling should be applied. The strata should be ranges of depth or relative density. When based on a relative density index the sampling effort should be proportional to density. Survey designs may also be guided by ecological information such as types of bottom preferred by the species, distribution of food organisms, etc. It will often be desirable to start work in a new area with a presurvey in which bottom topography, oceanography, fish distribution, behavior, etc., are studied as a basis for the final design of the survey. Patterns of behavior may affect both the technique and design of surveys, e.g. demersal fish often rise from the bottom by night or seasonally, and cannot then be sampled with bottom trawls.

Seasonal changes in both behavior and distribution are typical for many marine organisms and surveys should be repeated with special emphasis on periods of extreme environmental conditions. Year-to-year fluctuations in abundance or distribution are even more costly to evaluate in terms of research effort and time, but should always be considered in evaluations.

For typically pelagic schooling species no random sampling system will be practicable and the survey will essentially take the form of a search by sighting or acoustic instruments and sampling by fishing for identification and estimation of school sizes. If conditions favor the use of sonar, such instruments should be used and as far as possible also for direct abundance estimations (see below).

A detailed system of data logging and observations from sampling should cover the fishing operations, catch measurement and biological sampling, quality testing (e.g. fat content of fish), and environmental conditions. Procedures and proposed forms for such data recordings are described by Alverson (1971). The first analysis should take the form of a summary of data records issued on a current basis in tables and charts. For extensive surveys involving large amounts of data, storing and processing of data should be based on computer systems.

The first simple analysis is the distribution of relative abundance from catch rates of standard fishing operations, by total catch, species groups, and species. These should be related to environmental parameters if available. An analysis by depth is also usually relevant. Series of such distribution charts then form the basis for studies of movements and migrations.

If certain assumptions are made catch rates from standard hauls can be converted to measures of absolute abundance. For trawl gears this assessment involves an estimation of the total area swept by the trawl and the use of an assumed vulnerability coefficient for the fish within this area. A further important assumption is that there are no fish below the groundrope or above the headline, alternatively that their proportion can be assessed. For pelagic schooling species where total schools can be caught by purse seine, an abundance estimate may be based on counting of schools and sampling of school size.

From such absolute abundance measures an estimate of standing stock size can be made by area integration of density isopleth charts. For unexploited stocks this will then correspond to the virgin biomass of the exploitable part of the stock (with reference to the fishing method used).

Both Gulland (1970) and Alverson (1971) discuss methods of estimating the potential production of stocks from estimates of unfished stages of population size. From population models it is inferred that the greatest yield, C_{max}, is taken when the exploitable population is approximately one-half of its virgin biomass, B_0. As a rough approximation one may use the relation:

$$C_{max} = 0.5 \times M \times B_0$$

where M is the instantaneous coefficient of natural mortality.

For species with a relatively long life span, M takes values of the order of 0.2–0.4 and for such fish the maximum long-term yield will thus be of the order of 10–20% of the unfished stock. For short-lived species with a much higher natural mortality (e.g. Peruvian anchovy), the yield level will be closer to B_0. One cannot of course expect to be able to measure natural mortality in virgin stocks, and use must be made of relations between M and growth characteristics or longevity for a rough evaluation of this parameter.

As a method for exploring new resources fishing surveys have some clear advantages compared with other approaches. The most obvious one is that the whole range of information of a "fishery" character becomes available, such as catchability and vulnerability, gear efficiency, size and quality of the fish, and the diurnal and seasonal changes if such occur. Extensive biological sampling is also facilitated. Carefully planned and conducted trawl surveys for typical demersal stocks, e.g. shrimps and flatfishes, can provide reliable distributions of relative abundance and rough estimates of total stock abundance. For semipelagic and pelagic stocks one may encounter considerable difficulties in abundance measurements based on catch rates, and acoustic methods or a combination should be considered for such fish.

Exploratory fishing surveys are costly in terms of vessel requirements and are also time-consuming, even if the duration of standard trawl hauls is reduced to a minimum. All other available means of obtaining direct or indirect information on the distribution and behavior of the fish should therefore be used to make the survey as efficient as possible and avoid waste of effort. As an example can be mentioned the association of northern shrimp (*Pandalus* spp.) with soft bottom, which greatly facilitates the limitation of survey areas. Where other methods of abundance estimation are possible, e.g. by acoustic instruments, fishing programs should be limited to sampling for identification and biological data, and to experimental gear testing.

ACOUSTIC SURVEYS

Over the last 20 years or so echosounder and sonar surveys have gained wide use for studying the distribution and behavior of fish and assessing relative abundance of stocks. As an aid to fishing surveys, acoustic observation of fish distribution is indispensable for all but completely demersal organisms. In recent years considerable advances have been made in the technological and scientific basis of these methods, particularly with a view to permitting assessments of the absolute abundance of fish stocks. Further developments and refinements of methods will no doubt soon be forthcoming, but already it is clear that for pelagic and semipelagic fish direct estimation of absolute abundance based on acoustic observations is limited only by difficulties related to target identification and discrimination, and to a certain extent also by special features of fish behavior. But even in cases where the problems of target identification are not completely solved, an assessment of the combined abundance of several species occurring together may often be possible and the relative proportion of each may be roughly judged from sampling by fishing. Studies of behavior are particularly important for the successful use of acoustic techniques because both distributional characteristics and details of aggregation, dispersal, and vertical movements to and from the surface layers or bottom may greatly facilitate or complicate the work. Thus there is often a particular season, area, or time of the day or night that favors acoustic survey work. Fishing experiments with suitable effective gear, preferably of fully commercial type and size, will always form an indispensable tool for target identification and under certain circumstances also for checking and adjusting abundance estimates, particularly as regards school densities.

The instrumentation and techniques used for acoustic abundance estimation are relatively speaking of an advanced type, and require both "hardware" and "software" experts. This will be discussed further below. But even for simple applications of acoustics in fisheries research, the requirements for instruments and auxiliary equipment should be carefully considered. A wide range of echosounders and horizontal ranging sonars constructed for different requirements and applications are now available, and the cost of even the more sophisticated types will usually be only a fraction of the budget of a survey. For any scientific use only high performance and high resolution sounders with calibrated outputs should be used. Of equal importance is a careful installation to ensure low acoustic and electric noise levels. A further basic requirement is that the instruments fully calibrated so that observations can be referred to an absolute scale.

When using ordinary echosounders of the searchlight type, the echo from a fish of a given size will vary with the depth at which the fish is found: the greater the depth, the weaker the signal. Some echosounders compensate automatically for this by a TVG-function (time varied gain). This is a great advantage for abundance estimation and when surveying a wide interval of depth. A wide depth range can alternatively be covered with two different echosounders having different sensitivity settings for shallow and deep water. These are only some of a considerable number of important considerations in selecting acoustic equipment for a fishery survey vessel. Use of technical literature and manuals is recommended for further guidance.

The principles and methods of acoustic abundance estimation are fully described in a manual recently issued by FAO (Forbes and Nakken 1972). The basic principle is some form of quantification of the echoes returned by the fish. The presence or absence of recordings on an echogram is a first quantification, with measurements of the paper area covered by the fish trace as a further development. This simple way of estimating relative abundance has been used extensively in the preparation of charts of fish distribution. It is often found, however, that the degree of blackening of the echogram paper varies considerably, reflecting varying densities in the layers or schools of fish, and the simple trace-width method can be improved if supplemented with a system of grading classes. However, unless established by experimental fishing, the ratios between the true fish densities, to which the grading classes correspond, will remain unknown and charts will thus represent distributions of fish traces rather than of fish, and a total integration of the fish by areas will not be possible.

When fish occur in well-defined schools that can be counted with an echosounder or horizontal ranging sonar, the estimated number per unit area represents a relative abundance measure that can be considerably improved if estimates of school size can be included. School dimensions can be measured acoustically either by echosounder or sonar. When using an echosounder corrections must be made for the effect of the beam width and for the bias introduced because one relies on a single random cross section of the school. Horizontal ranging sonar only provides estimates of the horizontal extensions of the schools, so separate observations of their vertical extent must be made. In order to convert school numbers and school volumes into fish densities, experimental fishing must be carried out in a way that ensures that an entire school is captured in each set.

When fish occur dispersed so that echotraces appear separately, a simple count of number of single fish traces per unit distance is an index of abundance. But because the volume sampled by the echosounder varies with the target strength of the fish, i.e. the fish size, the number of traces counted is a poor estimate of the number of fish unless the size distribution remains constant. Within a defined spawning or feeding area, however, often only small variations occur in the size of the fish, and the simple trace counts may in such cases be a useful representation of fish density.

The sampling volume of the echosounder beam with reference to a particular size-range of a fish species can, however, be estimated and trace counts can then be converted to number of fish per unit volume of water or unit surface area. Estimation of the sampling volume of the instruments is indispensable for all measurements of absolute fish abundance based on acoustic observations only.

In "single-fish" distributions measurements of signal strength also permit the estimation of the acoustic target strength of the individual fish. The target strength may vary between species. It is for instance low in fish without swim-bladders such as mackerels. It is also a function of fish size and, if this function is known, the size distribution of fish can be estimated from the observed distribution of target strength.

Entire fish stocks or substantial parts of stocks are not commonly found in pure single-fish distributions with respect to acoustic detection even when high-resolution instruments are used. For multiple echoes signal averaging or integration techniques must be used. It can be shown theoretically that fish density is proportional to the square of the voltage of the echo signal it gives rise to, and this relation has been confirmed by practical experiments. The signal voltage can either be measured at time intervals or integrated over a distance, and the squared values will represent fish density. Such relative abundance indices can be converted to absolute measures of abundance by making use of target strength measurements of single fish of the species in question, or by counting the number of single fish that contribute to the integration values in surveys of single-fish distributions.

Between these various approaches to acoustic abundance measurements the integration technique seems at present to offer the most promising possibilities. Its successful use is, however, limited to certain conditions of fish distribution and behavior. The best conditions are found when the fish is distributed within a defined area, unmixed with other species, and in continuous scattering layers at moderate depth in midwater. Conditions are more complicated when the fish occur mixed with other species or in dense schools, and fish distributed close to the bottom or sea surface present special problems for the method.

Identification of the echo targets to fish species cannot in principle be made on an acoustic basis. On the other hand, studies of the characteristics of echo records and related measurements of signal strength offer a wide range of clues to the nature of the targets, and may often also permit estimation of their individual size. For a positive identification one must, however, always rely on sampling by fishing. Care should be taken to adjust the gears to be used to the probable size and type of the target organisms, bearing in mind processes of avoidance and selectivity. Use of acoustic netsonde instruments for trawls is indispensable. Other possible methods for identification include underwater photography, direct underwater observations, and the use of explosives.

When planning an acoustic survey, more flexibility in the program can perhaps be allowed than for exploratory fishing surveys. If possible the program should start with a "feasibility-phase" with the emphasis on studies of fish behavior and the main features of distribution and migration in order to find the best conditions for the acoustic survey. This may be related to spawning or feeding seasons. One may also find diurnal changes in the behavior pattern. Many species form schools during daylight and scattering layers at night. In surveys of such fish one should spend the day using sonar in search of areas with schools, and such areas should then be resurveyed the following night when the fish are dispersed in layers.

The density of the grid net should be adjusted to fish density in order to optimize abundance measurements. The survey grid must thus to a large extent be flexible and adjusted in accordance with the findings at all times during the survey. Fish concentrations are often located in larger units within certain areas; and a basic grid net designed so that it is dense enough to find these areas should be used and changed when an area is encountered and a denser coverage adopted. Often these fish field areas are related to particular environmental conditions, such as temperature–salinity fronts, upwelling areas, etc. Some guidance during the survey can therefore be obtained by regular observation of environmental parameters.

As to the need for repeated coverage over varying seasons, the same considerations apply as for exploratory fishing surveys.

The fishing program for identification will also provide samples for biological and quality studies of the fish. Observations of environmental factors should be made as part of studies of relations between the distribution and behavior of the fish and selected environmental factors. In addition to the data logging forms used in exploratory surveys, a carefully prepared acoustic log form should be used. Furthermore, in order that full use is made of all acoustic observations, and as a first step in the processing and evaluation of these data, it is important to establish a daily routine of scrutinizing the acoustic observations and data by all scientific and technical staff.

The data should as far as possible be processed more or less "on line" on board the vessel, and charts of fish distribution prepared on a current day-to-day basis. This is necessary for the adjustment of the program as the survey progresses.

In virgin areas assessments of stock size from acoustic abundance estimates represent unfished biomass, and the potential long-term yield must be calculated as mentioned in the previous section.

OTHER DIRECT METHODS OF DETECTION AND ASSESSMENT OF STOCKS

Visual observations of surface-schooling fish should be a programed routine for all vessel surveys and are particularly important for tunas, bonitos, and other fish whose behavior makes other survey methods difficult. Visual observations may sometimes provide clues to the identification of acoustic targets also.

Another and potentially important method for surface pelagic fish is airborne surveys. This has the great advantage of wide and rapid coverage. Both visual observations and various forms of recording by photographs with normal and infrared film and other remote sensing systems may be used. A special application is night recording of fish stimulated bioluminescence with low light level sensors.

Aerial surveying is limited by weather conditions, by certain features of fish behavior, and to a certain extent by turbidity of the surface water. For identification and sampling it must be supported by experimental fishing; and for studies of fish occurring below the surface, by acoustic surveys. Under certain conditions a combined aerial and acoustic survey may be the most economical and rational approach to assessment of pelagic stocks.

Remote sensing by satellites may in future make possible the identification and mapping of productive areas. Another possibility for identification and perhaps quantification of fish concentrations lies in the tracing and chemical identification of the minute quantities of organic compounds excreted by fish.

Concluding Remarks

It is hoped that the foregoing review of the various approaches to assessment of unexploited stocks may assist fishery administrators and research workers in choosing methods and planning such tasks. In the choice of methods, in addition to the technical/scientific points, a number of other criteria are of course also important. These include costs, availability of equipment and its servicing facilities, and availability of expertise. Financing may often be a limiting factor, but simple reflection will show that the investment represented by an adequate and well-planned resource survey will pay for itself many times over in the guidance that such a survey will provide for fisheries development both technically and in terms of economy.

Resource surveying should not be looked upon only as an activity that precedes fishery development. Monitoring of fish stocks and their state of exploitation is required for all fisheries on a continuous basis. The conventional methods of observing the reaction of the stocks to varying degrees of fishing pressures may be too time-demanding to provide timely management data for a rapidly developing fishery, and the method has also limited application for some types of fisheries, e.g. with purse seines, because of difficulties of effort measurement. Hence, the methods of resource assessment reviewed in this paper also have important applications beyond the initial stage of evaluating unfished stocks.

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Questions of Strategy in Fishery Management and Development[1]

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Fishery management draws on the fields of management in general, development, and fishery management. To make significant advancements in fishery management we need to invest in institutions that are capable of asking the right questions, to develop efficient means of making the proper decisions in respect to these questions, and most importantly, to develop the capability to effect actions which will facilitate these decisions.

We need to consider the complexity of the decision environment, and to have techniques for handling this complexity by insisting on analysis rather than intuition and on treating the fishery development problem as a system. The multiple-objectives problem needs to be grasped, and the questions of population dynamics need to be recast to explain departures from the existing simple models. We should consider in more detail the mathematics of programming theory. The most striking concept offered in this paper is that fishery management and development seem to be more preoccupied with tactics than with strategy.

The first concept of fishery management involves the complexity of the decision environment, resulting from increasing technological capability, the rising number of international differences, increasing communication among states, and the aspirations of developing countries.

The second is that because of these complexities more careful judgements must be made, and the scientific method employed more rigorously, including the use of systems analysis.

This requires that we view fisheries as systems, with resource problems separate from biological problems.

The fourth concept is that a broader view must be taken of the management process itself, which must be reviewed as a system. Further, management must appreciate biological, social, economic, and political objectives, and their complex interrelations. Many fisheries are said to be overcapitalized, but there have been few if any computations of optimal capital budgets, and little practical advice on strategies that can be followed by entrepreneurs. Economic objectives must be integrated into all the other objectives.

Biological questions relate to stock and recruitment, yield per recruit, and relation between catch and effort. The phenomena related to these processes are not sufficiently understood to produce predictions useful for management purposes. Some of the models used up to now are outmoded, mostly because they tell us how much can be caught from a single stock, while many stocks may be under exploitation simultaneously. Further, they do not face the major problem in fishery management — that of dividing the catch among those who wish to participate in the harvest. Divisions currently made do not always make sense from the economic or social point of view, and sometimes do not make biological sense. As an index of "sense" we might consider the benefits that could be accrued from a resource if it were owned by a single individual.

The mathematics of modelling for allocation of the catch is easy but the philosophical question of how to evaluate the various elements of the fishing process is not clear. Yet mathematical treatment allows a sharper focus of the problems, and allows us to look at a broader set of decision questions.

The sixth concept is that we need to achieve a simplification of our system. The most important simplification is to partition the problems into those that involve strategy, those that involve tactics, and those that involve operations. For development we wish to maximize the efficiency with which we transform resources into utility. There has been a general disappointment in the performance of development in recent years, and it is clear that economic criteria alone are not suitable for guiding development policy. Social welfare must also be integrated into the system.

To create a favorable environment for strategic decision-making it is necessary to have institutions that consider this problem in an explicit way; of particular relevance is the applied research institution to develop strategy.

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L'aménagement des pêches fait appel aux techniques de la gestion en général, du développement et de l'aménagement du secteur halieutique. Si l'on veut accomplir des progrès notables dans l'aménagement des pêches, il faut investir dans des institutions capables de poser les questions appropriées, mettre au point des moyens efficaces permettant de prendre les décisions nécessaires en réponse à ces questions, et par dessus tout, offrir la possibilité d'appliquer des mesures qui faciliteront ces décisions.

Nous devons envisager dans toute sa complexité le contexte dans lequel les décisions doivent être prises et disposer de techniques permettant de le faire en ayant recours plus à l'analyse qu'à l'intuition et en considérant les problèmes du développement halieutique comme un système. Le problème – qui présente des facettes multiples – doit être cerné et les questions liées à la dynamique des populations doivent être réexaminés afin d'expliquer les divergences par rapport aux modèles simples existants. Nous devons examiner de plus près l'aspect mathématique de la théorie de la programmation. La notion la plus intéressante exposée dans ce document est que l'aménagement et le développement des pêches semblent se soucier d'avantage de tactique que de stratégie.

L'aménagement des pêches est caractérisé en premier lieu par la complexité du cadre de décision—complexité due à l'accroissement des possibilités technologiques, aux différences internationales toujours plus nombreuses, à une communication accrue entre les Etats et aux aspirations des pays en voie de développement.

Il est également nécessaire, en raison d'une telle complexité, de formuler des jugements plus approfondis et d'appliquer de façon plus rigoureuse les méthodes scientifiques, notamment l'analyse des systèmes.

Pour cela, il faut que nous envisagions les pêcheries comme des systèmes, où les problèmes relatifs aux ressources sont distincts des problèmes biologiques.

La quatrième notion essentielle est qu'il faut considérer dans une perspective plus vaste le processus d'aménagement proprement dit et le concevoir comme un système. En outre, l'aménagement doit tenir compte des objectifs biologiques, sociaux, économiques et politiques et de leurs corrélations complexes. On prétend que de nombreuses pêcheries sont suréquipées, mais il n'existe pratiquement pas d'estimations sur le niveau optimal des budgets d'investissement et l'on dispose de peu de connaissances pratiques sur les stratégies que peuvent suivre les entrepreneurs. Il faut intégrer les objectifs économiques dans tous les autres objectifs. Les questions biologiques touchent les stocks et le recrutement; le rendement par recrue, et le rapport entre les prises et l'effort de pêche. Les phénomènes relatifs à ces processus ne sont pas suffisamment compris pour que l'on puisse formuler des prévisions utiles aux fins de l'aménagement. Certains des modèles utilisés jusqu'à présent sont dépassés, surtout parce qu'ils indiquent uniquement la quantité pouvant être prélevée dans un seul stock, alors que plusieurs stocks peuvent être exploités simultanément. En outre, ils ne résolvent pas le problème essentiel de l'aménagement des pêches – à savoir répartir les prises parmi les pays qui souhaitent participer à la pêcherie. Les répartitions actuelles ne sont pas toujours rationnelles du point de vue économique ou social, et parfois même du point de vue biologique. On peut considérer comme critère de rationnalité les bénéfices pouvant être retirés d'une ressource si elle était possédée par une seule personne.

L'aspect mathématique des modèles pouvant servir à la répartition des prises est aisé, mais le problème théorique posé par l'évaluation des différents éléments du processus de pêche n'est pas clair. Cependant, le traitement mathématique permet de mieux définir les problèmes et d'envisager un éventail plus vaste de questions appelant des décisions.

Le sixième principe régissant l'aménagement des pêches est qu'il faut simplifier notre système. La simplification la plus importante consiste à classer les problèmes selon qu'ils nécessitent la mise en oeuvre d'une stratégie, d'une tactique ou d'opérations. En matière de développement, nous souhaitons transformer de la façon la plus efficace possible les ressources à des fins utiles. D'une façon générale, les progrès ont été décevants au cours des dernières années et il apparaît clairement que les critères économiques ne suffisent pas pour orienter une politique du développement. Des mesures de caractère social doivent également être intégrées au système.

Pour créer un cadre favorable à la prise de décisions stratégiques, il est nécessaire de disposer d'institution capables d'envisager ce problème de façon lucide; les instituts de recherche appliquée sont particulièrement désignés pour mettre au point les stratégies nécessaires.

La regulación del sector pesquero incluye aspectos generales de reglamentación, explotación y regulación específicamente pesqueros. Para lograr progresos significativos en la regulación del sector de pesca es necesario suministrar fondos a instituciones que sean capaces de plantear los problemas adecuados, preparar medios eficientes para tomar decisiones oportunas sobre estos problemas, y sobre todo, estar en condiciones de intervenir en la forma necesaria para facilitar estas decisiones.

Hemos de tener en cuenta la complejidad del proceso de decisión y contar con técnicas para abordar esta complejidad insistiendo en el análisis más que en la intuición y tratando el problema de desarrollo del sector pesquero como un sistema. Es necesario captar el problema de la multiplicidad de objetivos, y reformular los problemas de la dinámica de las poblaciones para explicar la falta de coincidencia con los modelos sencillos actualmente existentes. Hemos de examinar con más detalle la matemática de la teoría de programación. El concepto más sorprendente que presenta este documento es que la ordenación y desarrollo pesqueros parecen ocuparse más de tácticas que de estrategia.

El aspecto más immediato de la regulación del sector de pesca es el relativo a la complejidad del proceso de decisión, debido al aumento de la capacidad technológica, el creciente número de diferencias internacionales, a la communicación que existe entre los estados y las aspiraciones de los países en desarrollo.

El segundo aspecto es que, a causa de esta complejidad, es preciso ser más cautos a la hora de emitir juicios, utilizando con más rigor el método científico, especialmente el análisis de sistemas.

Para ésto es necesario considerar las pesquerías como sistemas, en los que los problemas relativos a lo recursos se diferencian de los problemas biológicos.

En cuarto lugar, es preciso tener una perspectiva más amplia del proceso de regulación, que debe examinarse como un sistema. Además, en la regulación hay que tener en cuenta los objetivos biológicos, sociales económicos y políticos, y la compleja interrelación de los mismos.

Se dice que en muchas pesquerías hay un exceso de capitalización, pero son pocos o ninguno los cálculos que se han hecho, del presupuesto óptimo de capital y apenas existen consejos prácticos sobre estrategia a los que pueden ajustarse los empresarios. Los objetivos económicos deben integrarse en todos los demás objetivos.

Los problemas biológicos se refieren a poblaciones y reclutamiento, rendimiento por recluta, y relación entre captura y esfuerzo. Los fenómenos relativos a estos procesos no se entienden lo suficiente para preparar pronósticar que sean útiles a efectos de regulación. Algunos de los modelos usados hasta la fecha han quedado anticuados, la mayoría de ellos porque no dicen cuánto se puede capturar de una población, cuando se pueden explotar simultáneamente varias poblaciones. Además no tienen en cuenta el problema principal de la regulación del sector pesquero: la división de las capturas entre quienes desean participar en la explotación. Las distribuciones que actualmente se hacen, no siempre tienen sentido desde el punto de vista económico o social, y a veces ni siquiera desde el punto de vista biológico. Se puede considerar como criterio racional los beneficios que podrían obtenerse de un recurso si fuera propiedad de un individuo.

Los principios matemáticos en preparación de modelos para la distribución de capturas son fáciles pero el problema teórico de cómo evaluar los diversos elementos del proceso de pesca no esta claro. De todas formas, el proceso matemático permite enfocar más claramente el problema y percibir una gama más amplia de problemas relacionados con la decision.

El sexto punto es que necesitamos simplificar nuestro sistema. La simplificación más importante es dividir los problemas en tres tipos: de carácter estratégico, de carácter táctico y de carácter operativo. Con el desarrollo, lo que queremos es transformar con máxima eficiencia los recursos en algo útil. En los últimos años se ha producido una desilusión general por los resultados del desarrollo, y es evidente que los criterios económicos por sí solos no son adecuados para guiar una política de desarrollo. Es preciso integrar también en el sistema todos los aspectos de previsión social.

Para crear un medio ambiente favorable para tomar una decisión estratégica es necesario contar con instituciones que examinen este problema en forma explícita. Especialmente importante es una institución de investigaciones aplicadas para preparar una estrategia.

In Oddity Land

They're a rather peculiarly mixed up band . . .
I wish you'd remind me to bring them around
We'd all sit about on the floor and the ground
And talk about this and talk about that
Until we had a Very Nice Chat.
We might try to see if we can't agree
On whether there's too much salt in the sea . . .

In Oddity Land dogs ride on merry-go-rounds
This is a merry-go-round.

But if I keep chattering this way
I'll completely forget that I set out to say . . .[2]

that the purpose of this paper is to explore the extent to which the subject of fishery management and development resides in Oddity Land. The discussion relies to some extent on the tenets of system analysis as set forth by Churchman (1968).

The subject of fishery management and development requires definition. It draws upon the disciplines of management in general, development, and fishery management. The thesis explored is that to make significant advances in fishery management and development we need to concern ourselves with constructing and investing in institutions that are capable of asking the right questions in the area of resource management and development; developing the most efficient means for making proper decisions relevant to these questions; and, perhaps most of all, developing the capability to carry out activities which will facilitate these decisions.

When questions concerning fishery management are phrased in terms of population dynamics or economics, or are given as descriptions of the status quo, the questions are stated but frequently explicit attacks are not made on the strategy in fishery management and development. The thesis in this paper is that such an attack is needed. I have assembled a collection of concepts leading to considerations that can be useful when working out a strategy for fishery management and development.

These concepts have relatively little to do with the traditional view of fishery biology or fishery economics (these will, I am sure, be dealt with adequately by other speakers). They deal with the general problem of what kinds of things we need to think of when making resource development decisions. We need to consider, among other things, the complexity of the decision environment, the techniques for handling this complexity by insisting on analysis rather than intuition, and that the fishery development problem should be treated as a system. The multiple-objectives problem needs to be grasped, and even the questions of population dynamics need to be recast to explain departures from the existing simple models. The mathematics of differential equations should remain as a firm foundation for contemporary management problems, but we should consider in more detail the mathematics of allocation or programming theory. Perhaps the most striking concept offered in this paper is that fishery management and development seem to be more preoccupied with tactics than with strategy. Fishery management and development appear to have avoided the expertise of development economists, whose strategies of development would deal with the entire social–political system as well as the economic and biological features of the fisheries. The most important strides are made with practical well-focused regional-scale activities that emanate in response to local problems, rather than from the interest of the academician.

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[2] The above excerpts are from Edward Anthony's *Oddity Land* (1957).

The activity of management is essentially one of organizing and relating decisions. A better job of management will arise from developing a firm conceptual basis for the decision processes or rules of management. I will try to outline some of the concepts that go beyond the traditional scope of fishery management.

Complexity of Contemporary Decision Environment

The first concept involves the complexity of the present-day decision environment. This results from increased technological capability; from an increasing number of international differences generated by the influences of the developing states; from an increasing communication among states with differing political ideologies; and from the aspirations of the developing countries. The consequences of decisions that once could be analyzed by following a few relatively simple deductions must now be interpreted in the context of complex sets of interacting alternatives, as well as in the context of various secondary effects, each of which could explode into problems of even greater consequence than those originally contemplated.

This general problem of complexity in the context of development has been summarized by Gross (1972), who indicates that the world of development is favored by:

"1) more managers and administrators already familiar with various modern management practice and thought;
2) more local experts and technicians, including trainees returning from abroad;
3) more familiarity with the contributions and limitations of transnational technical assistance; and
4) more understanding by international agencies of the importance of administrative capability." However, he also notes that there are:

"1) *more complex problems:* with most developing countries facing growing difficulties in providing sufficient employment, housing, education, health services and other necessities for a rapidly expanding population;
2) *greater environmental uncertainties:* with rapid and unpredictable changes in human aspirations, social structures, coalitions of political power, government policies, and international relations in an emerging world society;
3) *more structural intricacies:* with more and larger organizations, increased specialization and professionalism, and more labyrinthine interrelations within and among organizations;
4) *more performance complexities:* with necessarily conflicting criteria governing organizational activities over large expanses of space, time, and psychic and cultural distances;
5) *uneven technological change:* with dramatic forward leaps in some areas, particularly the military, and comparative backwardness in many others;
6) *unsettling effects of technological change:* with every technological change undermining the status and power of people accustomed to the older ways of life;
7) *the obsolescence of yesterday's innovators:* with yesterday's brilliant men focusing attention on the perfection or use of techniques increasingly irrelevant to tomorrow's problems;
8) *the spreading "Fallacy of Administration as Technical Gadgetry":* with specialized techniques of analysis or control mistakenly viewed (or fraudulently advertised) as substitutes for genuine managerial wisdom, judgement and the more profound developments in managerial approaches;
9) *increased "Brain Drain":* with more modern-style managers and technicians from developing nations moving into positions of higher psychic and monetary reward in developed nations; and
10) *larger "Managerial Gaps":* with a few organizations in developing nations developing advanced managerial capabilities, while others will still not have advanced very far beyond the culture of the ox-cart, the heritage of colonialism or the crude "scientific management" of the early twentieth century."

While the goals of fishery development may at first glance depend on whether this management is to take place in a developed or developing country this does not materially affect the ensuing discussion because, as Gross observes, the first eight of the above factors apply to both. These problems are very evident in fisheries. I have given a view of this situation elsewhere (1971) and italicize in this version a passage that seems particularly appropriate to the present state of world fisheries in the setting of this Conference: ". . . where individual fishing operations can exert tremendous intensities of fishing effort and deplete a stock in a matter of weeks or months; where the number of overexploited stocks continues to grow; where some stocks continue to become virtually extinct; and *where the community of individuals who harvest and process the stocks are, in many instances, neither held accountable nor do they demonstrate a responsibility to conserve the stocks by not overfishing, by not insisting on and supporting research of relevance to fishery problems; and by not contributing needed management data or by contributing data that either contain an inordinate amount of errors or are not timely.* These complexities require that the contemporaneous manager face the above questions and answer even more complex questions concerning how resources should be allocated in the time stream, how resources should be allocated among the states, and how criteria should be established to evaluate the resources so that appropriate allocations can be accomplished."

The Need for Systems Methodology

A second concept is that because of these complexities we need to develop approaches that will efficiently sort out the best alternatives to attain our objective of better resource decisions. In the process we will need to attain further wisdom and exercise more careful judgement in developing criteria that generate an appropriate balance between the social good and the private good. We need to evaluate distinctions between goals of economic welfare and goals of social welfare. Finally we need to make the right decisions that enable us to utilize effectively the alternatives chosen.

The traditional approach in fisheries usually involves either the "muddling through" approach (see Lindblom 1959) or the scientific method. "Muddling through" is based on intuition, and while it is frequently used, there is not much to recommend it. The scientific method, as Quade (1964) pointed out as early as 1964, is not very helpful either, because it seeks contributions to knowledge, understanding, and predictive ability, whereas what we really need is a methodology that both suggests policies and offers a list of alternatives to decision-makers, along with an interpretation of the consequences of each alternative. We need a methodology that aids in the development of policy philosophy: such a method is systems analysis (see Churchman 1968; Hare 1967; Rothschild 1971, 1972b).

Systems analysis begins by formulating objectives; next, alternative ways of reaching the objectives are decided upon; criteria are then developed to judge among the alternatives; and a plan of action is formulated based upon the best alternative. The systems methodology places considerable stress upon cycling through this procedure iteratively, because in systems analyses the objectives are a variable, and after each iteration the analyst should know more about the nature of the problem than when he becan the previous cycle, thus enabling a reiteration of the objectives. The analysis essentially stops when further iterations do not yield a reformulation of the objectives.

The Need to View Fisheries as a System

The third concept is that if we are to use systems analysis to attack fisheries problems we need to view fisheries as a system or a collection of systems. These fishery systems generally constitute a resource problem or a set of resource problems, which are distinct from biological problems in that they involve the linkages between a portion of the biota and man's use of it. These linkages involve biological questions, but they are not necessarily more important components of the linkages than the social, the political, and the economic questions. For any of our fishery resources it is very difficult to demonstrate that we have properly allocated our intellectual and financial resources to maximize the efficiency of these linkages. The fundamental problem of fishery development might very well be the mobilization and allocation of financial and intellectual resources to solve natural resources problems, which by definition involves the development of algorithms or rules for making the right decisions. The inefficient mobilization or misallocations of talent are evident in many circumstances, e.g. when a fishery is managed as a single-species fishery when in fact it catches several species. Another example is when the total disciplinary spectrum is not considered, e.g. the economic aspects but not the biological problems, or vice versa. An even more insidious misallocation of talent is paying lip service to being multidisciplinary. This Conference might do so by having a section on fishery science and methodology, one that deals with the economic aspects of management and development, and a section concerned with technology, but at the end do we merely staple these components together and call this very act of stapling a multidisciplined approach. Do we return to our offices and at some mysterious future date rise, not unlike the fabled Kraken, to attend the next great stapling? Or, on the other hand, do we examine the difficulties and constraints that prevent full utilization, formulate these as problems on a practical regional scale, then proceed systematically to achieve solutions? Being only nominally multidisciplinary will not produce results of multidisciplinary utility, and because of this the more efficient multidisciplinary approaches will in the long run be discouraged.

The Need to Take a Broad View of Management

The fourth concept is that if we are to view fisheries as a system or a collection of systems, then in addition to taking a broad view of fisheries problems we must also take a broad view of the management process itself. Management must be viewed as a system (Blumenthal 1969). This has been discussed by Drucker (1969) as the "new realities" of management, which I have quoted and paraphrased as follows (1971): ". . . all institutions will have to make fulfilment of basic values, beliefs, and purposes a major objective of their continuing activities rather than (having) a social responsibility that restrains or lies outside their primary functions. Further, the quality of life is, in fact, a business opportunity and can be converted into profitable business. There should be more emphasis on adapting the institutions to the needs, aspirations, and potentials of the individual than on adapting the individual to the demands of the institution." Entrepreneurial innovation was not formerly intrinsic to management, but now such ". . . innovation will become the very heart and core of management . . . Existing institutions will have to reach out for changes as an opportunity, (and) will have to learn to resist continuity." Management should also make knowledge more productive, and here Drucker points out that in the production of knowledge there is no single best way to doing a job and ". . . there can be no divorce of *planning* from *doing* in knowledge work."

Drucker further points out that management should ". . . be considered as both a science and a humanity." In this respect ". . . management is . . . a culture and a system of values and beliefs and serves as a channel through which society can productively utliize its values and beliefs," and final emphasis is placed on noting that "economic and social development are the result of management." Thus, for example, ". . . there are not underdeveloped countries. There are only *undermanaged* ones."

Multiple Objectives

The fifth concept acknowledges that if management is to be developed from a rationale that includes inter alia biological, political, social, and economic considerations, then management must appreciate biological, political, social, and economic objectives. Optimizing any one of these may produce advice that is totally unrealistic. The biological, political, social, and economic objectives are by themselves complicated and the manner in which they interrelate is even more so. Additional problems are generated when we remember that the questions of interrelations among objectives must extend among states that are at different stages of development as well as among those with differing economic ideologies. The fundamental question is whether these complications really reflect some unresolvable problems, or whether they result from inadequate attention to the interdisciplinary areas. These areas really have not been examined with the same explicit attention as have the biological or the economic areas. We therefore need to examine the problems in a systematic way. Because the systems approach is iterative, after our initial formulation of the problem we may learn that the interrelations among the disciplines are really not complicated; they may simply appear to be complicated because of the lack of genuine interdisciplinary study. We will consider in turn economic, biological, development, and research objectives. Social objectives will be touched upon in the section on development.

ECONOMIC OBJECTIVES

Economic objectives involve questions of economic efficiency, the relation between marginal cost and marginal value, and the fact that the return on any investment should be favorable when compared with alternative investments (Panel Report of the Commission on Marine Science, Engineering and Resources 1969). From these higher-level goals there have been studies partitioning various returns to investment, labor, etc. (Smith, undated). While there is a growing body of literature indicating that many fisheries are overcapitalized it is somewhat curious that, to my knowledge, optimal capital budgets have not been computed for any of these fisheries; it is then logically difficult to claim overcapitalization. While theory gives us guidance on questions of economic efficiency we have not had much explicit advice on practical strategies that can be followed by fishery entrepreneurs on a practical everyday basis. Large-scale economic efficiency cannot be attained until the components of the economic system make decisions that are consonant with the rules that appertain to the larger system. The above difficulties, as well as the roots of the multiple social welfare functions, have been discussed by Crutchfield (1972). He hoped "... that the late 1960s marked the end of simplistic controversies over the relative merits of maximum sustained physical yield versus maximum net economic yield as the objectives of fishery management."

Crutchfield went on to review some of the basic problems of the economic and political objectives of fishery management. He identifies several troublesome issues: a, Small groups of "winners" tend to be more influential in constructing a policy that benefits the winners to a greater extent than the long-range public interest; b, There is a zero opportunity cost for what may be an apparent inefficient employment of fishermen; c, It is difficult to appraise the benefits from a fishery that fishes multiple stocks in the same geographic area (e.g. a groundfish fishery) or fisheries that are mobile, fishing several geographical areas (e.g. the U.S. tropical tuna fishery, which fishes in the eastern tropical Atlantic), in terms of benefits accruing from a single stock; d, The range in per capita incomes among countries makes the question of allocation among them difficult. In addition, Gulland (1968) shows how the international disparity among labor and other costs can encourage increased fishing effort in a fishery that is already "overfished"; e, The emphasis placed on various objectives is not the same in different political systems; different desires for foreign exchange, for "status" in fisheries, and for maintaining options for the future (the last highlights one of the essential features of these problems, which relates to the different discount rates with which the various states perceive the various objectives).

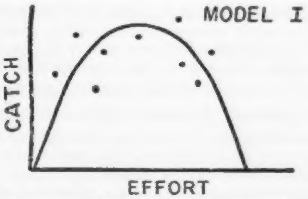
BIOLOGICAL OBJECTIVES

The biological objectives of management involve relatively simple technical computations. It is important to understand that while there are great complexities concerning the biological objectives — in particular those that concern stock and recruitment — these are relatively simple technical problems relative to the problem of taking a holistic view of fishery management and development.

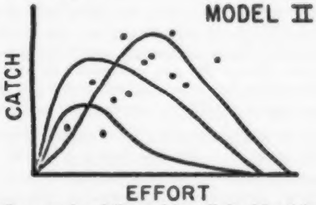
The biological questions basically are related questions of stock and recruitment, yield per recruit, and the relation between catch and effort. While the question of stock and recruitment is of immense scientific importance, and an understanding of the question of the magnitude of recruitment as a function of time may very well be one of the fundamentally most important aids to fishery decision-making, the fact remains that the phenomena associated with these processes are not sufficiently understood to place general utility upon recruitment predictions for management purposes. The yield per recruit concept involves determining that combination of fishing mortality and minimum size that maximizes yield per recruit. As multiple gear fisheries become more complex, it becomes very difficult to estimate the appropriate minimum size. Besides, while it is possible to regulate minimum size by adjusting mesh, for example, it has always been difficult to adjust fishing effort. In fact, it is probably because of this difficulty that the term eumetric fishing was coined. The main value of the yield per recruit approach is to achieve an understanding of the effect of changing recruitment size, mortality rate, and growth rate upon the relation between catch and effort. This is perhaps the relation that provides the most important information for the decision-maker. I have discussed the interpretation of the relation between catch and effort in some detail (Rothschild 1971). In essence this discussion concentrates upon explaining departure from the traditional model which, using standard notation, is:

$$\frac{dP}{dt} = \phi(P) - FP$$

It is usually fitted by least squares giving a regression line so that the situation of Model I is achieved (Fig. 1). Any deviation from the line is a random component and we



strive for the equilibrium conditions represented on the line. But nature does not stand still; we cannot expect the constants in the above equations to remain constant. The "constants" are in fact random variables, and as such they are drawn from particular distributions (which we hope will remain constant). This means that each year the parameters are different and so the model then becomes as in Model II of Fig. 1.



The difference in philosophies elicited by Models I and II could be considerable. In I we always strive for the "golden equilibrium"; in II the equilibrium differs each year owing to changes in the scale of F (that is, $F = qf$ implies that q is a simple constant of proportionality between F and f, but in reality q should be considered as a functional operator ø, say, which could be complex) and changes in the stock structure and the usual vital parameters. This means that it is worth investigating the mechanisms that change the spatial distribution of the stocks, the vital parameters, and the function implied by the operator.

When integrated with economic considerations this philosophy enables a "program" (in the technical mathematical programing sense) of fishing in which by Model I we would be underfishing in some years and overfishing in others. However, our program would allocate inputs to the fishing process over a sufficiently long time such that outputs would be maximized. The methodology for such a program could be obtained from the theory of linear programing as is done in forestry or from dynamic programing, which is more realistic but sometimes computationally difficult (but note some computational simplifications in dynamic programing afforded by stochastic dynamic programing — Howard 1960). See also the analytic versions presented by Booth (1972) and Quirk and Smith (1970). Until these theories are utilized the manager will be faced with various empirical approaches such as that most recently suggested by Gulland (1972) for shrimp management:

"a) Examine the extent of the area involved, and estimate, on the basis of comparison with other areas the likely number of trawlers required for operations at the optimum level (for example 50).

b) Issue licenses for the operation of rather less than this optimum number (say 30). A condition of obtaining a license would be provision of full statistical data on the operations, including catches of each size of shrimp, fishing effort and location of fishing.

c) Allow the operation of these vessels for 2 or 3 years without modification. Then examine the statistical and other data, assess the stocks and obtain a revised estimate of the optimum number of vessels, (e.g. 55) this may be above or below the original estimate.

d) Issue further licenses to bring the total number of vessels licensed closer to, but still below, the revised estimate of the optimum (e.g. 45).

e) Make economic studies to estimate the likely profitability of each boat when the fleet approaches its optimum size.

f) Decide, particularly if this profit is large, what use should be made of it, and introduce appropriate additional conditions on license holders, e.g. substantial license fees, commitment also to land defined quantities of fish, etc.

g) Repeat steps c) to f) at intervals."

The reason that the techniques of stock and recruitment, yield per recruit, and the relation of catch-and-effort are simplistic and in a sense anachronistic is not because of any intrinsic failure in the techniques; nor is there any implication that these techniques are not extremely useful interpretative devices. The strictly biological interpretation of these models is not now a major problem since the importance of the value metric has been stressed in the literature for some decades. But it is still not generally recognized that some concepts of management can provide incentives for gross overcapacity, or that MSY as a concept can be economically disadvantageous because if it is not responsive to supply and demand it can generate undesirable fluctuations in price. The major anachronism is that these models simply advise us on how much can be caught from a single stock; but by modifying some of the growth and mortality rates they can show us how to modify the total catch. This in itself is an important problem because it involves the methodology for increasing the supply of fish, which unfortunately tends to be submerged when discussing management. The major difficulty with these models from a decision point of view is that they do not face what is perhaps the major problem in fishery management, that of dividing the catch among those who wish to participate in the harvest. The central question of fishery decision-making – fishery management – is how to allocate the resource in space and time. The other major problem is to increase the supply of fish.

We are continually answering the question of "who gets what," since as long as the catch is shared by at least two entities an allocation is performed. But allocations made implicitly do not always make sense from an economic or social point of view, and one could point to a number of examples where they do not make biological sense. As an index of "sense" we could consider the benefits that could be accrued (and then distributed) from a resource if it were owned by a single individual, and compare these to the benefits that actually accrue under post hoc ergo propter hoc allocation. The after-the-fact allocations are similar to after-the-fact policies. I have discussed the analysis remedy for after-the-fact overdetermined policies (Rothschild 1972), and the same remedy of analysis would apply to allocations.

ALLOCATION MODELS

Because allocation models are so unusual in fisheries – a seeming paradox – the subject is worth a bit of discussion. For example, with respect to allocating the catch there is a rich framework in the theory of mathematical programing that deals with this. While there have been a few attempts (e.g. Rothschild and Balsiger 1971; Booth 1972; Quirk and Smith 1970), the problem has not really been addressed in depth mainly because, while the mathematics are easy, the philosophical question of how one evaluates the various elements of the fishing process is not entirely clear, although the formulation of these problems in mathematical terms can be helpful in sharpening the questions that can be asked. For example, in salmon management the traditional technique involves allowing sufficient "escapement" (the fish that escape the fishery and are therefore able to spawn). But when formulating the salmon problem as a programing problem we can give many more options to the systems design. For example, Rothschild and Balsiger (1971) maximized:

$$Z = \sum_{i=1}^{M} \sum_{j=1}^{N} c_{ij} X_{ij}$$

subject to:

$$X_{ij} \leqslant R_{ij}$$

$$\sum_{i=1}^{M} X_{ij} \leqslant K_j$$

$$\Sigma \Sigma a_i X_{ij} \leqslant T - E$$

$$\Sigma X_{ij} \leqslant M - \frac{E \times H}{F}$$

$$\sum_{j} X_{ij} \leqslant S_i - L_i$$

where: M = total number of age-sex categories; N = total number of days in the run; X_{ij} = number of fish caught in the *i*th age-sex category on the *j*th day of the run; c_{ij} = value of a fish caught in the *i*th age-sex category on day *j* of the run; R_{ij} = number of fish of the *i*th age-sex category that run past the fishery on the *j*th day; K_j = capacity of the cannery or canneries in numbers of fish on the *j*th day; a_i = average number of eggs in each fish in the *i*th age-sex category; T = total number of eggs contained in the escapement and catch; E = minimum number of eggs required in the escapement; M = total number of males in the escapement and catch; H = sex ratio desired in the escapement, expressed as the number of females per male; F = average fecundity of the female age-sex categories, expressed in number of eggs; S_i = number of fish in the total season run of the *i*th age-sex category; L_i = number of fish of the *i*th age-sex category desired in the season's escapement.

Putting the problem in this context allowed us to look at a much broader set of decision questions than is conventionally examined in salmon management. In the "who gets what" context we are allocating different kinds of salmon (identified by age, sex, and day of "entrance" into the fishery) among the catch, taking into account a daily processing capacity, a seasonal processing capacity, and a requirement to allow a certain number of eggs and male fish to survive the fishery for reproductive purposes. Because of the way the model was formulated we could simultaneously study the unused catch or escapement, the unused cannery capacity, and the number of eggs that could be caught and were not. The formulation further enabled us to impose a value to different sizes and sexes of fish, to a salmon egg, and to an empty unit of cannery capacity. These important values are the kinds of information that need to be accounted for in the decision process. The analysis led to further interesting results showing how fish that were ordinarily of less value could become more valuable than fish of greater value.

We have used another example of linear programing to study production functions in fisheries, where we allocated two species of tunas among three size-classes of boats to provide guidance on optimum tuna fleet composition (Rothschild 1972a). In the discussion we indicated the simple extension for allocating the catch among countries. As we try to bridge the gap between the inputs to the fishing process we can see that the usual fishing power calculations are not sufficient to measure and analyze the inputs because these have chance components that need to be handled explicitly. We developed a model for this, evaluating the quality of different decisions in terms of the entropy perceived by the decision-maker. We further gave an example of how the large variances sometimes encountered in fishery work could be treated explicitly.

In reviewing the subject of traditional dynamics we would be remiss if we did not mention the most recent advances, developed by Ricker (1948) and exemplified more or less simultaneously by Gulland (1965) and Murphy (1965), which have been facilitated by computer computation. These derive from the virtual population methods and enable the estimation of fishing effort as a function of age. The second important technique is that of generalizing the production function developed by Pella and Tomlinson (1969). For a recent discussion of the production model, see Fox (in press). For a review and detailed example of the application of these methods the reader is referred to the paper by Abramson and Tomlinson (1972).

GOALS IN DEVELOPMENT

A further set of goals needs to be considered — those for development. An example of these may be found in the Provisional Indicative World Plan for Agricultural Development (FAO 1970). While these relate mostly to agriculture there is no reason why fishery development cannot be guided by them:

"a) Providing the future food supply, with population typically growing at 2.5 to 3% a year.

b) Adjusting to the still more rapid increase in the number of people who can only be reached through marketed output, as well as the changes in the compostion of the diet that accompany urbanization and rising incomes per capita.

c) Adjusting to the specific requirements in food policy, which emerge from the analysis of the main dietary deficiencies (especially protein quality) inherent in the present

composition of food intake under the major dietary patterns.
d) Assuring the raw material base for the processing industries (food and non-food), which are usually dominant in the early stages of industrialization.
e) Earning and saving foreign exchange. Shortage of the latter is one of the most serious bottlenecks to economic growth in most developing countries and most of them depend mainly on agricultural products to earn it. On the other hand, in a great many countries the agricultural sector offers considerable scope for economic import substitution. In more general terms the agricultural sector has a significant part to play in the mutual enrichment of all countries through expansion of international trade based as far as possible on comparative advantage.
f) Providing a large part of the additional employment that will be needed over the period up to 1985; and at the same time permitting some of the increase in the labor force to become available for nonagricultural occupations through an increase in labor productivity on farms.
g) Contributing to the savings needed to finance development.
h) Helping in the diffusion of wealth, which alone can provide a mass market for industry, not to speak of an adequate effective market for agricultural products. The greater part of the population in most developing regions is still agricultural, so that without prosperity here, the whole process of economic development is thwarted.
i) Providing a market for "producer goods" industries, that is farm machinery and equipment, fertilizers, chemicals for control of pests and diseases."

The goals of a research organization and the kinds of information that are applicable have been discussed by Rothschild and Uchida (1968: 46–48).

Simplification Through a Distinction Between Tactics and Strategy

The sixth concept is that we need to achieve a simplification of our system, given the complexity of the contemporaneous decision environment, the availability of a methodology to handle the complexity, the need to view the fisheries as a broadly based system, the need to consider the management of a system from a similarly broad viewpoint, and the complex multiple objectives associated with fisheries. System simplification can be attained in a variety of ways (Hare 1967). One approach is to partition the problem into its components and concentrate on the most important one. Another is to rely on various mathematical techniques to help synthesize the quantitative aspects of the problem. Perhaps the most important simplification was formulated by Anthony (1965), who noted that decision problems could be divided into those that involve strategy, those that involve tactics, and those that involve operations.

In an earlier paper (Rothschild 1971) I considered Anthony's strategic tactical breakdown in terms of the fishing question in the strict sense, where the annual catch is the strategy, and the methodology of obtaining the catch is the tactics. In the present paper I follow Gross (1972), and regard the following distinctions between strategic and tactical decision-making:

Strategic approach	Tactical approach
Broad scope	Narrow scope
Long time-horizon	Short time-horizon
Formulates problem	Seeks objective answer to problem formulated by others
Systems oriented	Operations research oriented
Considers relation of problems to other problems	Considers only solution of particular problem
Concentrates on desirability	Concentrates on feasibility and consistency

If, for example, we consider tactics without considering strategy we could very well be answering the wrong questions, even though perhaps with considerable skill. For the broad questions of fishery management and development we may be concentrating on tactics without having a well developed strategy. Clearly we need to inquire as to the appropriate strategy for fishery management and development.

Development

The seventh concept is that of development. It is complicated by the fact that in the context of fisheries it can mean development in the usual sense, that is, related to the developing countries, or it can mean the development of an underdeveloped industry in a developed country. We can have a developed fishing industry in an underdeveloped country, an underdeveloped fishing industry in a developed country, or an industry undeveloped in the sense that it does not make the most efficient use of available resources.

In the international context the development of fisheries must be responsive to the general international development problem. This is reflected in a number of indices that demonstrate the gap between the "haves" and the "have nots." One commonly used index of the quality of life is the per capita GNP; poor countries are those with a per capita GNP which is less than the world mean per capita GNP (Bhagwati 1966).

There are other measures of the quality of life such as literacy, infant mortality, physicians per capita, etc. The responsibility of the developed nations for facilitating the development of the developing nations is outlined by Myrdahl (1972). Recognition of the need for international development stimulated the United Nations to consider the 1960s as the Decade of Development. While there were some increases there has been a general disappointment in the average development performance during that decade. A diagnosis of the reasons may help us to put in perspective some of the problems in the narrower field of fishery management and development. In a diagnosis of the problem associated with development during the 1960s, Robinson (1971) pointed out that the theme for generating development at that time was the "economic plan." "Essentially, the rationale of the plan was to mobilize economic resources and deploy them on cost–benefit criteria to projects with optimal effects on economic growth rates and structures." Robinson synthesized several views on the best alternative plan for development:

"The view of Ramaswami and Ikram states that in South Asia agriculture would not be a primary sector in development because farm surpluses increase at a lesser rate than rural population; only industrialization can provide a quantum jump for the economy. This industrialization would create a better capital–output ratio than would agricultural development through

- large amounts of capital quickly
- provide resources for its own development
- import substitution which saves foreign exchange."

Robinson furthermore points out that there were reservations associated with the above view of "industrialization": rapid industrialization would likely call for more foreign exchange than would be available; industries would be inefficient owing to stagnation of agricultural incomes.

If the development process concentrates upon industrial technology, then the gap between rural and urban incomes will increase, and migration into urban areas will be encouraged, but as technology advances jobs will be destroyed. This will achieve a high output–capital ratio, but the costs in terms of widespread unemployment and political unrest will be great.

Robinson (1971, p. 3) continues by quoting E. F. Schumacher:

"Industrial concentrations based on the latest technology may give you the best output for capital invested and the best rate of economic growth; but the political and human costs in unemployment in the countryside, in resentment against a policy that leaves 80% of the nation in rural areas worse off than they were before, are so great that society (may) disintegrate and the economy run down."

Dr. Schumacher suggests that the answer lies in the development of "intermediate technologies" that are prosecuted in rural as well as urban areas.

A third point of view, that of Prof. N. Kaldor, is to develop optimal capital output projects in urban areas and then redistribute the income to rural areas; but this would generate difficult political problems. It turned out that the "best of plans based on maximum productive efficiency may yet make bad economic policy." Robinson notes that . . . "the imperious, economic approach in which economic stages and models, economic factors and economic criteria reigned almost unchallenged in principle, as arbiters of development strategy. The tendency of the style was too optimistic. It exaggerated the actual power of economic over noneconomic factors . . ."

From these excerpts we can see that questions of development are wide reaching and that economic criteria by themselves are not suitable for guiding development policy. It is necessary to reconcile questions of social welfare with questions of economic growth. What all this shows is that development is not an economic process or a technological process; it is a process whereby the quality of life will be better tomorrow than it is today.

Since our goals involve increasing the supply of fish through management, increasing the supply of fish through discovery of new stocks, and developing more efficient processing and marketing linkages, we might simply develop programs to undertake attaining these three objectives. Unfortunately there are many such programs, and while they are capable of solving technical or tactical problems, there are not as many successes as one might hope in making better resource decisions. The major problem in both developed and developing countries lies in decision-making institutions, and the major problem in institutional development is that of developing an institutional strategy. This is not a fishery problem per se, but it is relevant since it is the general development problem. Gross (1971) characterizes it as being reflected in organizations that exhibit: a deep-rooted resistance to change, ritualistic rather than genuine planning, and lack of managerial (or administrative) capability. He further observes that the "world of development administration is peopled too much by dinosaurs and ostriches. The ostriches keep their heads and eyes snugly buried in the warm sands of ancient memos and bureaucratic fantasy. The dinosaurs bask in the memory of past struggles for freedom, blind to the world-shaking changes that threaten new forms of servitude. Both are encouraged in these attitudes by the example, advice, or misleading information provided by richer ostriches and more powerful dinosaurs in the so-called "developed" nations. Neither has one of the most important virtues of an administrator . . . the ability to understand rapid and complex environmental changes and help his organization adapt creatively to these changes."[3]

While in some cases the above may be an overstatement it is still quite clear that administrative ability is a considerable constraint on development.

It is generally realized that fishing problems are characterized by underlying roots of conflict generated by "who gets what," but it is not clear that the science of conflict study has been explicitly applied in the fishery area.

Institution Development

The eighth concept is that in order to create a favorable environment for strategic decision-making and the framing of problems in a strategic context, it is necessary to have institutions that consider this problem in an explicit way. While there are many institutions that relate to fisheries, there is one type particularly relevant to our considerations, the applied research institution that can provide the driving force to develop strategy. To build such an institution it is necessary to develop various properties in functional terms. We thus eliminate the usual organizational hierarchy and provide the research institution with a strategy instead of merely factors of the organization. A functional organization might include the following: clearly identified strategies and tactical components; clearly identified participants, operations, and functions; an acknowledgment that participants include "customers" and that an organization's goals can be determined by conducting market research upon the customers; a specific mechanism for communicating with customers; a group of individuals with the specific task of providing accountability in the system; flexibility in program structure so that the tactical operations consist of a mix of

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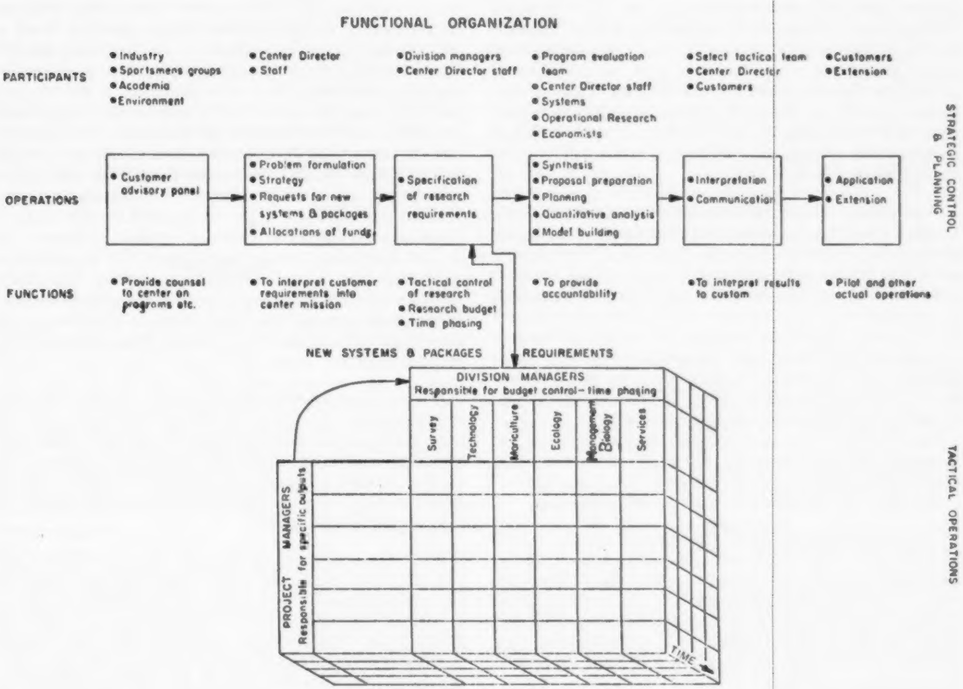
[3] *Appraising Administrative Capability for Development*, p. 10. INTERPLAN Report, Public Administration Division, 1969 (United Nations Sales No. E.69. II.H.2).


FUNCTIONAL ORGANIZATION
PARTICIPANTS
• Industry
• Sportsmens groups
• Academia
• Environment
• Center Director
• Staff
• Division managers
• Center Director staff
• Program evaluation team
• Center Director staff
• Systems
• Operational Research
• Economists
• Select tactical team
• Center Director
• Customers
• Customers
• Extension
OPERATIONS
• Customer advisory panel
• Problem formulation
• Strategy
• Requests for new systems & packages
• Allocations of funds
• Specification of research requirements
• Synthesis
• Proposal preparation
• Planning
• Quantitative analysis
• Model building
• Interpretation
• Communication
• Application
• Extension
FUNCTIONS
• Provide counsel to center on programs etc.
• To interpret customer requirements into center mission
• Tactical control of research
• Research budget
• Time phasing
• To provide accountability
• To interpret results to custom
• Pilot and other actual operations
STRATEGIC CONTROL & PLANNING
NEW SYSTEMS & PACKAGES
REQUIREMENTS
DIVISION MANAGERS
Responsible for budget control—time phasing
Survey
Technology
Mariculture
Ecology
Management Biology
Services
PROJECT MANAGERS
Responsible for specific outputs
TIME
TACTICAL OPERATIONS

projects, each with a starting and stopping date enabling a shift of personnel among projects rather than keeping specialists within their own more or less narrow disciplines. Such a system is presented in Fig. 2 above.

Approaches to Strategic Decision

The ninth concept is that if we are to develop responsive institutions, then these institutions will need to be built upon the principles of strategic decision-making as outlined, for example, by Gross (1972). Students of fishery management and of development hold considerable differences in opinion concerning the scope and the nature of appropriate solutions in their respective fields. A common thread does exist, the acknowledgement of the complexity and the need to find simplifications that make solutions more attainable. An important simplification involves decomposing a problem into its strategic and tactical elements and letting the elements of strategy guide the programed tactical decisions. Gross (1972) outlines principles of strategic decision-making that I shall paraphrase and annotate. These are: responsible decision-making, conflict essence of problems, selectivity, total system appreciation, relative proportions, sequential model-using (the art of modelling through), problem interrelations, jointed incrementalism, organized and unorganized interests, the emotional basis of rational action, investment in future capabilities, and power mobilization and use.

Responsible decision-making — The strategic decision-maker has a responsibility to deal directly "with changing patterns of multiple purposes and objectives and handle all relevant variables, including those that may be immeasurable or noncommensurable"; to view one's own decision-making in a matrix of others with possibly conflicting decisions, and to realize that each decision changes the decision environment; to be innovative and to create new values and norms that will elucidate problems that have been previously "swept under the rug" because these did not previously exist, and to "subordinate (without overlooking) technical considerations of both feasibility and consistency to longer range considerations of desirability"; and to generate the most appropriate forms of tactical analysis.

Furthermore, "if tactical, nonresponsible decision-making tends, in the absence of a strategic framework, to dominate the decision-making process, then this may be properly called irresponsible decision-making."

Conflict essence of problems — Conflict is particularly characteristic of fishery resource problems. Owing to the tactical nature of fisheries, it tends to ignore the "identification of the parties at conflict and appraising their strengths and their interests, both apparent and actual" as well as the evaluation of the various "conflict outcomes: avoidance, deadlock, defeat or victory, compromise and integration." It is clear that our decision-making needs to take more explicit account of the conflict essence of problems.

Selectivity — One would think that this simple concept, which advises the decision-maker to examine his alternatives and concentrate upon the best set of alternatives, would be rather generally applied, but "many national planning and development documents are tragic monuments of failure in strategic selectivity. Too often they are built on the double principle of a) stringing together separate plans or programs emanating from every major ministry, or b) providing something for every active pressure group and region. This "laundry list planning" sometimes approaches sheer irresponsibility."

Many fishery programs, whether in developed or developing countries, have the above characteristics. Our fishery institutions tend to be structured in a way that encourages this incremental management approach.

Total system appreciation — Suboptimization is a characteristic of a nontotal system view of a problem. If the complexity of the fishery system is not acknowledged this will lead to suboptimization whereby one element of the system, such as the design and construction of a fish plant, may be optimized but the total system ignored. For example, if the supply of fish is ignored it will be impossible to operate the plant.

Relative proportions — This concept demonstrates the inadequacy of priority lists for making decisions. One simply "cannot order the parts of a system;" thus it is necessary to think in terms of "relative proportions." Inasmuch as many fishery decisions are made on the basis of priorities, the relative proportions concept needs to be considered more often.

Sequential model-using (the art of modelling through) — The main point made by Gross is that model building is a scientific endeavor, but model using is an activity employed by decision-makers. Because the model builder often has different objectives than the model user (i.e. the decision-maker), the models produced are usually interesting but not necessarily useful. This reiterates the need for model building to be a sequential iterative process in which the builder interacts with the user so that the model is dynamic rather than static. A good model should mean, not be. Decision-making need not be "muddling through," but it must be "modelling through." Insofar as there are only a limited number of fishery models that actually apply to decision-making, it is difficult to see a widespread applicability of this important technique. This suggests a need for developing additional fishery models.

Problem interrelations — This is another reflection of problem complexity mentioned earlier.

Jointed incrementalism — "A good example is the process of building new development institutions. Thus, in reconstructing an agricultural bank inherited from a colonial period or in building a new institution of this type from scratch, a myriad number of very small, incremental decisions must be made over a rather long period of time. These involve the selection and training of personnel, the mobilization of resources, the development of methods and procedures, the formation of various linkages with farmers, government agencies and other institutions, successive internal reorganizations, etc., etc. If these thousands of steps are pursued on the basis of disjointed incrementalism, the end product is likely to be a rigid institution that operates more like a traditional bank than like a true development agency. Successful institution building is possible only if there is a long-range general model that can serve as a guide to the thousands of incremental decisions. This means jointed incrementalism."

Organized and unorganized interests — The strategic decision-maker needs to consider not only the extent of organized and unorganized interests, but those that will be either organized or unorganized in the future. The strategic decision-maker needs to include within his repertoire the kinds of decisions that can awaken and organize appropriate interests.

The emotional basis of rational action — There are basically two modes of communication, the objective and the emotional. The function of the objective mode is to transmit information, that of the emotional mode to evoke action. The strategic decision-maker must realize that his task most frequently goes beyond simply transmitting information; he needs to elicit action and thus he must develop techniques that utilize an understanding of the emotional basis of rational action.

Investment in future capabilities — In addition to considering investment in terms of the conventional "hard" terms it is necessary to appreciate investment in all areas of management. "a) Investing in people, through education, health, scientific research, and other services or facilities that may make people more productive. b) Investing in the organization and institutions that put hard goods and people together in producing goods and supplying services. c) Investing in the administrative capability that is required to guide organizations and institutions . . . In a certain sense, investing in administrative capability covers all the other aspects of investment, in that administrators – particularly at strategic levels – are directly concerned with continuing decisions on hard goods, people, organizations and other administrators."

Power mobilization and use — The point is made that the strategic decision-maker wants action; plans that do not stimulate action are not particularly useful. The activation of plans involves: "(1) building a support network (or activation base) and (2) the use of various modes of influence (or changing "activation mixes") including persuading, pressuring, and promoting self activation." Gross notes that this is essentially a political process and that politics has been called the art of the possible, but the strategic decision-making in the development area frequently involves intrinsically competing concepts and here we have the art of the improbable.

The above principles are not often considered in fishery management or fisheries strategy. They lie beyond the perimeter of Oddity Land, providing a checklist of items that need to be ticked off before entering the details of a problem in fishery development. Do we consider these items in fishery management and development? How are these items covered in this Conference? What is our philosophy on the strategy of fishery management and development?

Discussion

In discussing the problem of fishery management and development we have assembled a variety of concepts and assertions. The first of these is that there is such a place as Oddity Land. I have never been there, but they tell me that visas are not too difficult to acquire. On the outskirts of Oddity Land they recognize the complexity of the contemporary decision environment and this complexity is characteristic of the decision processes in developing and developed countries. Because of the complexity, advanced informational techniques are needed to analyze alternative means of achieving multiple objectives and developing criteria. Fisheries must then be viewed as systems, and an important simplification of the fishery system is to partition it into its strategic and tactical components. Travellers tell me that in Oddity Land many of the inhabitants consider only questions of tactics and not questions of strategy. Some of the leading citizens do tend to think of doing things the right way, although I understand that one of their number was deported for this. He had thought about responsible decision-making, the conflict essence of problems, selectivity, total system appreciation, relative proportions, sequential model using, problem interrelations, etc.

Now one might think that to make some positive accomplishment in fishery management and development all we need is some system analysis, a dash of operations research, a pinch of social science, etc. Indeed, as Gross notes, these techniques have been to some extent "sold" to developing countries by a variety of foreign governments, international agencies, private companies, special advisors, consulting firms, management institutes, scientists and researchers. But frequently, as Nathaniel Hawthorne noted, "Thus it is that ideas, that grow up within the imagination and appear so lovely to it and of value beyond whatever men call valuable, are exposed to be shattered and annihilated by contact with the practical."

How do we achieve the practical? How do we get away from Gross's cast of characters? "a) The "humble and obedient" civil servant: "I just carry out policies set by the Government . . ."; b) The technical expert: "Let's concentrate on efficiency, and thus release more resources for those humanistic matters . . ."; c) The economic strategist: "We'll be able to enjoy the luxuries of humanism if we tighten our belts today and concentrate our resources in capital investment . . ."; d) The ostrich: "This is not a problem . . ."; e) The dinosaur: "This proves we shouldn't get involved with these fancy new management techniques . . ."

The answer is relatively simple. We need to build new institutions that are capable of facing explicitly the concepts outlined in this paper. These institutions should be chartered to find solutions to practical fisheries problems on a regional scale.

In building these institutions it will be necessary to examine existing fishery arrangements, such as was undertaken by Kasahara and Burke (MS), and also to develop new organizational patterns that help rather than inhibit fisheries organizations in coping with the problems of supply and management in a general development setting. If we do this we may need another conference because the technical questions of fishery management and development do not really explicitly address these questions of strategy. We need to stop describing the present and move dynamically into planning the future.

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Fishery Management in the Northeast Atlantic: the Role of the International Council for the Exploration of the Sea[1]

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LEE, A. J. 1973. Fishery management in the northeast Atlantic: the role of the International Council for the Exploration of the Sea. J. Fish. Res. Board Can. 30: 2031–2037.

Rational management by the North-East Atlantic Fisheries Commission (NEAFC) is aided by scientific advice given to it by the International Council for the Exploration of the Sea (ICES). Such advice is provided through a Liaison Committee consisting of the Chairmen of eight Area- and Sub-Committees and five co-opted members. The members of the Liaison Committee act on their own and not on behalf of governments or other bodies. Advice comes to a large extent through working groups, which pass their views to the Liaison Committee. This decides what advice to pass to the commission. The responsibility of the Liaison Committee is to see that the advice is scientifically sound and based on adequate information.

There are 23 working groups covering the main fisheries of the region. They usually meet early in the year and the Liaison committee considers their reports in February, to prepare its own report for circulation one month before the commission meeting in May. This tight timetable is becoming more difficult to meet as NEAFC calls for advice on more stocks. It is complicated by the fact that other meetings (notably that of the International Commission for the Northwest Atlantic Fisheries) are held at about the same time, and that many scientists are involved in both; there are not enough to do all the work.

The great strength of ICES is that it is a scientific forum as well as being a scientific advisory body to NEAFC. A major concern in recent years has been the dependence of recruitment on parent stock. Nearly all the demersal fisheries of the area have come under mesh and minimum size regulations; attention is now focused on the pelagic fisheries and on methods of management involving control of the total amount of fishing and the assignment of catch quotas. This will call for improved methods of stock assessment. More reliable estimates of future recruitment are also essential.

ICES has been ahead of public opinion in respect to concern for the environment, and an Advisory Committee on Marine Pollution has been established which is analogous to the Liaison Committee, and provides advice to the council.

International agreement in fisheries is slowed by three factors. Conflicts of interests among nations are lessened in the ICES–NEAFC framework because of the way in which the Liaison Committee is constituted. Fisheries biologists are conservative when it comes to providing advice on which decisions are made, with a tendency to wait for more data or to reach agreement on the lowest level when opinions differ. It would be better in some cases to offer a range of alternatives. Scientists also have an obligation to inform the commission of their views on all developments and not wait until their advice is sought. Finally, while theory lags behind events, there is an increasing tendency for ICES scientists to give commissioners early warning of the effects of various developments.

Prior disclosure to NEAFC of national plans that would affect fishing would be helpful in making earlier advice possible. There is also need for various countries to strengthen their capability to carry out research in stock assessment and to provide statistics and associated biological data quickly. Agreements on these aspects were reached at the Special NEAFC Meeting at the level of ministers, and at the Stockholm Conference. It is hoped that these can be implemented soon.

La Commission des pêches de l'Atlantique nord-est (CPANE) reçoit du Conseil international pour l'exploration de la mer (CIEM) des avis scientifiques qui lui sont donnés par l'intermédiare d'un Comité de liaison, composé des présidents de huit zones et sous-comités et de cinq membres cooptés. Les membres du Comité de liaison agissent pour leur propre compte et non pour celui de gouvernements ou d'autres organes. Les avis émanent pour la plupart de groupes de travail qui les communiquent au Comité de liaison, lequel décide ce qu'il convient de transmettre à la Commission. La responsabilité du Comité de liaison consiste à s'assurer que les avis sont scientifiquement sûrs et fondés sur des renseignements dignes de foi.

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February, 13–23, 1973.

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Il existe 23 groupes de travail couvrant les principales pêcheries de la région. Ils se réunissent d'ordinaire au début de l'année et le Comité de liaison examine leurs rapports en février afin de préparer son propre rapport pour diffusion un mois avant la réunion de la Commission, en mai. Il devient difficile de respecter ce strict calendrier car la CPANE demande des avis sur un plus grand nombre de stocks. La tâche est encore compliquée par le fait que d'autres réunions (notamment celle de la Commission internationale des pêches de l'Atlantique du nord-ouest) se tiennent à peu près en même temps et qu'en raison du nombre insuffisant de spécialistes, beaucoup d'entre eux sont appelés à s'occuper des deux régions.

La force du CIEM tient à ce qu'il est à la fois un centre d'échanges de données scientifiques et un organisme consultatif auprès de la CPANE : on s'est beaucoup préoccupé ces dernières années de devoir dépendre, pour le recrutement, de stocks de reproducteurs. Presque toutes les pêches démersales de la zone ont été soumises à une réglementation sur les mailles des filets et sur la taille minimum des poissons. On s'attache maintenant aux pêches pélagiques et aux méthodes d'aménagement qui impliquent le contrôle des captures totales et l'allocation de contingents de prises. Ces mesures exigeront des méthodes améliorées d'évaluation des stocks; ainsi que des estimations plus sûres du recrutement futur.

Le CIEM a devancé l'opinion publique dans ses inquiétudes au sujet de l'environnement et un Comité consultatif sur la pollution des mers, analogue au Comité de liaison, a été crée pour fournir des avis au Conseil.

La conclusion d'un accord international sur les pêches est ralenti par trois facteurs : les conflits d'intérêts entre les nations perdent de leur acuité dans le cadre du CIEM–CPANE du fait de la composition du Comité de liaison; les biologistes des pêches ne donnent qu'avec prudence des avis sur les décisions à prendre et ont tendance à attendre que des données plus nombreuses soient disponibles ou à réaliser l'accord sur le niveau le plus faible lorsque les opinions diffèrent; il serait parfois préférable d'offrir une gamme de variantes. Les spécialistes sont aussi tenus de communiquer à la Commission leurs points de vue sur tous les faits nouveaux sans attendre d'être sollicités; enfin, bien que la théorie soit en retard sur les évènements, les spécialistes du CIEM tendent de plus en plus à avertir sans tarder les membres de la Commission quant aux incidences des divers facteurs nouveaux.

Afin que les avis puissent être donnés plus tôt, il serait utile que la CPANE soit à l'avance mise au courant des plans nationaux susceptibles d'affecter les pêches. Il faudrait aussi que divers pays renforcent les recherches sur l'évaluation des stocks et fournissent rapidement des statistiques et les données biologiques connexes. Des accords à ce sujet ont été réalisés à la réunion spéciale de la CPANE, tenue au niveau ministériel, ainsi qu'à la Conférence de Stockholm et l'on espère qu'ils prendront bientôt effet.

En sus actividades de racionalización de la explotación, la Comisión de Pesca para el Nordeste del Atlántico (NEAFC) cuenta con el asesoramiento científico del Consejo Internacional para la Exploración del Mar (CIEM), que dispone para ello de un Comité de Enlace compuesto por los presidentes de ocho comités zonales y subcomités y por cinco miembros designados por cooptación. Los miembros del Comité de Enlace actúan en nombre propio y no en nombre de sus gobiernos o de otros organismos. El asesoramiento procede, en buena parte, de grupos de trabajo, que transmiten sus puntos de vista al Comité de Enlace, quien decide sobre el consejo que ha de darse a la Comisión. Al Comité de Enlace toca velar por que su asesoramiento esté bien fundado científicamente y se base en información adecuada.

Existen 23 grupos de trabajo, que se ocupan de las principales pesquerías de la región. De ordinario se reúnen a principios del año, y el Comité de Enlace examina sus informes en febrero, para preparar el suyo de manera que pueda distribuirse un mes antes de la reunión de la Comisión, que se celebra en mayo. Este calendario tan ajustado presenta cada vez mayores difficultades, a medida que la NEAFC pide asesoramiento sobre más poblaciones. Resulta además complicado por el hecho de que, al mismo tiempo, aproximadamente, se celebran otras reuniones (especialmente la de la Comisión Internacional de Pesca para el Nordeste del Atlántico) y muchos científicos participan en ambas; no hay, pues, personal bastante para hacer todo el trabajo.

La gran ventaja del CIEM es que, al mismo tiempo que un organismo científico asesor de la NEAFC, es un centro de debates científicos. Uno de los temas principales de que se ha preocupado en los últimos años ha sido en qué medida el reclutamiento depende de la población de progenitores. En casi todas las pesquerías demersales de la zona se ha regulado la luz mínima de la malla; en la actualidad, se atiende sobre todo a las pesquerías pelágicas y a los métodos de regulación que entrañan un control de la actividad pesquera total y la asignación de cupos de captura. Esto hará preciso disponer de mejores métodos de evaluación de poblaciones. También es esencial disponer de estimaciones más fidedignas del reclutamiento en el futuro. El CIEM se ha adelantado a la opinión pública en su preocupación por el medio ambiente, y ha creado un Comité Asesor sobre Contaminación Marina, análogo al Comité de Enlace, que asesora al Consejo.

Los acuerdos internacionales en el sector pesquero se ven frenados por tres factores. Los conflictos de intereses entre países se reducen dentro del CIEM–NEAFC por la forma en que está constituido el Comité de Enlace. Los especialistas en biología pesquera son prudentes cuando se trata de aconsejar qué decisiones han de tomarse, y tienden a esperar a disponer de más datos o a llegar a un acuerdo mínimo, cuando las opiniones difieren. En algunos casos, sería mejor ofrecer toda una gama de posibilidades. Los científicos tienen además

la obligación de comunicar a la Comisión sus puntos de vista sobre todos los nuevos acontecimientos, sin esparer a que se les pida su parecer. Por último, aunque la teoría está rezagada respecto a los hechos, los científicos del CIEM tienden cada vez más a advertir oportunamente a los miembros de la Comisión de los efectos de las diversas novedades.

Para que fuera posible asesorar más tempestivamente a la Comisión, sería útil que se comunicaran a la NEAFC con antelación suficiente los planes nacionales que afectarán a la pesca. Es necesario que varios países intensifiquen sus investigaciones sobre evaluación de poblaciones y faciliten rápidamente datos estadísticos y otros datos biológicos afines. A este respecto se ha llegagado a un acuerdo en la reunión especial de ministros de la NEAFC y en la Conferencia de Estocolmo. Se espera que sea posible llevar estos acuerdos pronto a la práctica.

IN a contribution to this conference, Dr Lucas has discussed the subject of the provision of scientific advice to fisheries bodies and has dealt at length with the essentials upon which such advice must be based and with the types of information and research that are required for rational fishery management. The purpose of my notes below is to outline the particular arrangements whereby scientific advice is provided for the North-East Atlantic Fisheries *Commission (NEAFC) by the International Council for* the Exploration of the Sea (ICES). At the present time I am acting as Chairman of the Consultative Committee and, hence, the Liaison Committee of ICES and as such I am responsible for ensuring that the required advice is provided and that it is the best obtainable in prevailing *circumstances. The opinions expressed in the notes* concerning the efficacy of the existing arrangement are my own and they have not been discussed with my colleagues in the ICES Consultative and Liaison Committees or with the ICES Secretariat.

International Council for the Exploration of the Sea

The council is an intergovernmental body with 19 member countries at present, as follows: Belgium, Canada, Denmark, Finland, France, Germany (Federal Republic), Iceland, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Spain, Sweden, United Kingdom, and Union of Soviet Socialist Republics. It was founded in 1902 as a result of, firstly, a desire among European scientists to foster international cooperation in marine biology and hydrography in order to obtain a better understanding of the North Atlantic and its adjacent seas and, secondly, a growing concern about the need to adopt regulatory measures in order to conserve North Sea fish stocks in view of the marked increase in fishing effort that had recently come about with the development of the steam trawler. The subsequent history of the council and its work have been described by Went (1972, 1973) and by Cushing (1972); it is not my intention here to go over the historical material once again, but instead to review where ICES stands with regard to the provision of scientific advice related to fisheries management.

In 1937, largely as a result of discussions within ICES, 10 European countries signed a convention on the protection of undersized fish, but the second world war prevented its ratification. In 1946, again mainly as a result of ICES activity, this convention was replaced by an Overfishing Convention covering the Northeast Atlantic and signed by most European countries. Following ratification of this second convention the Permanent Commission was formed in 1954, and in 1959 the North-East Atlantic Fisheries Convention was signed establishing NEAFC. Article 11 of this convention states "In order that the recommendations made by the Commission for the conservation of the fish stocks shall be based so far as is practicable upon the results of scientific research and investigations, the Commission shall when possible seek the advice of the ICES."

LIAISON COMMITTEE

In order to provide such advice ICES established a Liaison Committee under the chairmanship of the person holding office as the Chairman of the Council's Consultative Committee. At the present time the Liaison Committee *consists of the Chairman of the following Area- and* Subject-Committees: Demersal Fish (Northern), Demersal Fish (Southern), Pelagic Fish (Northern), Pelagic Fish (Southern), Shellfish and Benthos, Anadromous and Catadromous Fish, Statistics, and Gear and Behaviour. They are joined by a number of co-opted members (five at present) chosen on account of their individual knowledge of various fields of fisheries research, and the Council's Statistician acts as the Secretary of the Committee.

When giving advice to NEAFC the Liaison Committee acts on behalf of the Council. Its members, when they act as the Committee, are responsible to no body other than the Council. They cannot be under any national instructions or under instructions from any of the Council's Area- or Subject-Committees. The Liaison Committee may, if it finds it useful or desirable, institute certain working procedures in order to ensure that the advice it gives to NEAFC is based on as broad as possible a consensus of opinion in the relevant field. This may include hearing the views of Area- and Subject-Committees before it decides upon the advice to be given. No committee or working group of the council can give advice direct to the Commission; it must pass its views to the Liaison Committee. If a working group meets after the Liaison Committee's meeting but before the commission's meeting, the Chairman of the Liaison Committee may, if he feels it useful or desirable, inform the commission about the group's report and conclusions, but this does not represent an advice to the commission until it has been specifically accepted as such by the Liaison Committee itself. The committee is free to select from the reports and recommendations of working groups and Subject- and Area-Committees and from other sources such information as it wishes to transmit to the commission. It may find it useful, as is often the case, to append certain working group reports to its own report to the commission, but it is under no obligation to do so. It is free to draw its own conclusions from the material presented by a working group, or to accept wholly or partly the group's conclusions. The only responsibility of the Liaison Committee is to see that whatever advice it passes on to the Commission is, to the best of its knowledge, scientifically sound and based upon sufficient and adequate information.

PROCEDURE

NEAFC holds its annual meeting early in May and makes specific requests to ICES for advice on particular fish stocks. These requests are considered at the Statutory Meeting of ICES in October and it is usual to establish a series of working group meetings in order to deal with them. The working groups at present in existence are listed in Appendix 1. They total 23 and it can be seen that they cover all the main demersal and pelagic fisheries in the northeast Atlantic. Their meetings tend to take place round about the turn of the year in order to ensure that the most recent annual sets of statistics are available, and the Liaison Committee considers the reports coming from these meetings and from the Statutory Meeting when it meets in February in order to prepare its report for the next meeting of NEAFC. This report has to be circulated by the Secretary of NEAFC so as to reach commissioners at least 1 month prior to their annual meeting. It is published as an ICES Cooperative Research Report shortly after that meeting, and so the advice given by the Liaison Committee is made publicly available.

This timetable is tight and it is becoming ever tighter as NEAFC calls for advice concerning more and more stocks as they come under increasing fishing pressure. To give an example, as many as six working group meetings were scheduled to be held in the first few weeks of 1973 in order to allow the Liaison Committee to prepare its report for the 11th Meeting of NEAFC in May 1973. The organization of this series of meetings is complicated by the fact that the International Commission for the Northwest Atlantic Fisheries (ICNAF) also holds a midterm meeting in January, and that too seems to be increasing in length. The scientists from European countries taking part in the ICNAF meeting are the same as those participating in the meetings of the various ICES working groups and committees. They are few in number and it is clear that they are operating at present with too great a work load. This situation might be remedied to some extent by joint discussions between NEAFC, ICNAF, and ICES aimed at designing a better timetable, but to my mind the real solution lies in increasing the number of stock assessment experts in the various national laboratories and, in this respect, it is encouraging to note that at the Special NEAFC Meeting at the level of ministers held in Moscow in December 1972 ministers agreed on the importance of a, extending the range and scope of fisheries research; b, an increase in cooperation and joint scientific programs; and c, an improvement in the supply of statistics by member countries.

ICES A SCIENTIFIC FORUM

The great strength of ICES lies in its being a scientific forum for the exchange of information and ideas and for the promotion of investigations for the study of the sea, particularly those relating to living resources, as well as being the scientific advisory body to NEAFC. The first function allows fishery science to develop independently of the special requirements of NEAFC and hence to anticipate them to some extent. It also brings together both pure and applied scientists from a number of different disciplines and hence provides a multidisciplinary approach to a number of problems, e.g. those concerned with the biology and physics of fishery ecosystems and with the effects on fish stocks of environmental changes. Further, although ICES is an intergovernmental organization, it draws to its meetings experts from universities and research councils as well as government fisheries laboratories, and it is thus very much an open forum at which both governmental and non-governmental views can be expressed. It must be noted, however, that in recent years the scientific proceedings of some of the Subject- and Area-Committees have tended to suffer because of the time involved in dealing with the increasing amount of routine business that results from the need to provide advice to NEAFC.

Major Topics of Scientific Discussion

Major topics of scientific discussion within ICES in recent years have been the dependence of recruitment on parent stock, the regulation of total fishing effort by the introduction of various kinds of quota systems, and the effects of marine pollution on fisheries.

RECRUITMENT

Recruitment failures have occurred in recent years in the Atlanto-Scandian and Downs stocks of herring in the Norwegian Sea and the North Sea, respectively, and in the Arcto-Norwegian cod stock in the Barents Sea. All these stocks had been under the pressure of heavy fishing before the failure occurred, and it was argued by some scientists that the latter was due to the low level of the spawning stock resulting from the fishing pressure. This concept of the dependence of the level of recruitment upon the level of the parent stock was in a sense unorthodox to most ICES scientists in that their stock assessment has been based largely on the yield per recruit model of Beverton and Holt (1957) and the assumption of constant recruitment regardless of stock size. ICES therefore sponsored in 1968, jointly with ICNAF and FAO, a symposium on the general problem of stock and recruitment. No general solution of the problem was forthcoming but its study and discussion have continued and, in the case of some stocks, they have been made more complex because work in the hydrographic and meteorological fields has revealed another possible cause of recruitment failure in that marked fluctuations in the climates of the atmosphere and seas of northwest Europe have been contemporaneous with the growth of fishing effort and the recruitment failure.

REGULATION OF TOTAL FISHING EFFORT

From the end of the second world war until the early 1960's ICES was largely concerned with mesh regulation and minimum size limits as tools for fishery management. All the major demersal fisheries of the northeast Atlantic are now subject to this type of regulation. More recently a need has grown for the management of the major pelagic fisheries and for more effective measures with which to regulate demersal fisheries and, arising from discussions with ICES, NEAFC has now started to move towards a consideration of management whereby the total amount of fishing is controlled by means of quota systems. To date it has not been possible for the commission to adopt these because all Member Countries have not yet approved the resolution adopted at its eighth meeting that grants it the power to issue recommendations to the member countries on the regulation of catch and fishing effort and their distribution between countries. However, in 1971 a closed season was introduced for North Sea herring fishing following consideration of a report submitted by the ICES North Sea Herring Assessment Working Group; and Norway, Iceland, and the USSR have held discussions outside the framework of the Commission in order to agree upon a quota system for the Atlanto-Scandian herring stock. Similar discussions are proceeding between Norway, the USSR, and the UK with regard to the Arcto-Norwegian cod stock.

The introduction of quotas will call for an improvement of stock assessments. ICES has already pointed out to NEAFC that in order to achieve this it is essential to a, improve greatly the coverage, accuracy, and speed of reporting of national statistics; b, extend substantially the biological sampling programs (the amount of such sampling carried out at present differs considerably between countries and is far from proportional to the quantity of fish caught by the individual countries); and c, augment the type of data used up till now in making assessments by other information in order to permit more accurate estimation of stock size and recruitment. With rapid changes in the fisheries and with the introduction of catch regulation, the comparability of the present abundance indices will become less and less precise. They are based on long established national patterns of fishing. Closed seasons, closed areas, or quotas will disrupt these patterns, making it essential to obtain estimates of stock size independent of catch and effort data, e.g. by means of acoustic surveys and tagging experiments. In this connection ICES, in collaboration with FAO and ICNAF, held a *Symposium on Acoustic Methods in Fisheries Research* in Bergen in June 1973.

Another essential requirement for management is a reliable estimate of future recruitment to the fishery. For some stocks this is already monitored by means of larval, 0-group, and groundfish surveys. These surveys require high investments in time and effort by research vessels. Provisions must be made for considerable increase in such investments and for the expansion of international cooperation in these types of research activities if scientific management of the stocks is to become a reality. It will also be necessary to consider the exploitation of various stocks in relation to each other, in that the limitation of the fishery for one stock of a particular species may bring about increased exploitation of another stock elsewhere, either in the NEAFC area or outside it, e.g. in the ICNAF area. A start into the investigation of this problem has already been made by the Joint ICES/ICNAF Working Group on Cod Stocks in the North Atlantic. Furthermore, quota regulations on a particular species may lead to increased fishing on stocks of other species hitherto only lightly exploited, and hence give rise to a need for their management as well. Such a development would, of course, be a welcome step towards the greater use of available resources.

MARINE POLLUTION

As far as marine pollution is concerned, ICES has to a considerable extent been ahead of public opinion in its concern for the environment. Studies of the pollution of the North Sea and Baltic Sea have been under way for 5 years and the Council is at present conducting an International Study of the Pollution of the North Sea and its Effects on Living Resources and their Exploitation. Progress to date has been described by Lee (1972). Salient points in the study are the determination of the levels of toxic substances in fish and shellfish in order to guard against risks to human health, and the mapping of the pattern of heavy metal pollution in the North Sea to see if there are "hot spots" that could be critical for commercial species of fish during the various stages in their life histories. ICES has also established an Advisory Committee on Marine Pollution for providing scientific advice on marine pollution and its effects on living resources and their exploitation to member governments and any intergovernmental body for the control of pollution that may request such advice. This committee is analogous to the Liaison Committee. It is constituted in such a way as to provide the best possible scientific advice, and its members, when acting as the committee, are responsible to no body but the council.

CHANGES IN NORTH SEA FISH STOCKS

During the last two decades some striking changes have taken place in the landings from the North Sea fisheries, the present level being about double that in the early 1950s. These changes are due in part to increased fishing effort, but they have also been caused partly by the appearance of very large year-classes of some species. Shifts in fishing patterns to new species, size categories, and fishing grounds, and natural fluctuations in the marine environment may also have played a part that is not yet fully understood. In order to promote the investigation of this matter and to provide guidance for future ecological research and the better management of multispecies fisheries, ICES has decided to hold a *Symposium on the Causes of Changes in North Sea Fish Stocks*, preferably in the summer of 1975, and it has already appointed a Planning Group to develop a prospectus for the symposium and to identify the kinds of data concerning the fish and shellfish stocks and their environment (physical, chemical, and biological) that will be required in order to provide a synoptic picture of the changes that have taken place since the second world war. The symposium will therefore be concerned to some extent with each of the main themes of ICES activity described above in that it will deal with the interaction between species under varying degrees of exploitation, with the variations in recruitment in response to changes in stock size and in oceanographic and meteorological conditions, and with the effects, if any, of marine pollution.

Factors Delaying International Agreement

Cushing (1972) in his study of the history of some international fisheries commissions states that international agreement in the field of conservation is obtained slowly because: a, there are conflicts of interest which increase with the number of nations involved; b, fisheries biologists tend to be a little conservative in their science when confronted by the need for action; and c, theory has lagged behind events and will continue to do so. Taking these factors into consideration within the ICES–NEAFC framework, while it is true that conflicts of interests occur between nations within NEAFC, in my view they are relatively few within ICES because of the manner in which the Liaison Committee is constituted and the way in which it operates. There are, of course, differing scientific points of view on some issues; these can even occur within national delegations. But a scientific body that did not have within it such differences would not be a healthy one. It is also true that fisheries biologists may be somewhat conservative, particularly when they are responsible for providing information upon the basis of which decision-making will proceed. There is then a tendency to play safe and to wait for more data and, when a division of opinion occurs, to reach agreement at the lowest level. In some cases when advice is asked for it would be better to state a range of alternatives that are governed by the limits of our present knowledge of the various factors involved, rather than wait and seek more detailed data in the hope of obtaining a precise answer later. When the former course of action is adopted it should not be used as an excuse by commissioners for delaying action on their part on the grounds that absolute scientific proof is first required: Gulland (1971) has already made apt comment on that tactic. For their part, fisheries scientists also have an obligation to keep commissioners informed of their views on all developments that come to their knowledge and not wait until their advice is called for. At all times they should communicate their views to commissioners in clear and easily understandable language, avoiding the jargon of their trade but stating the constraints within which they have had to work in preparing their assessments. Nevertheless, a measure of brevity is also required and it is of interest to note in this connection that ICES is at present endeavoring to prepare for commissioners a concise review of our knowledge of the life history and state of exploitation of the main fish stocks of the NEAFC area.

Finally, theory does indeed lag behind events, but I think that there is an increasing tendency for ICES scientists to try to give commissioners early warning of the effect of various developments within the European fishing industry. A move on the part of individual commissioners towards the prior disclosure to NEAFC of any national plans to increase significantly the amount of fishing effort deployed upon a particular stock might help in this respect in that it would assist ICES to give advice at an earlier stage than now. There is also a need for national moves in various countries to strengthen the two essential bases for scientific advice: firstly, the capability to carry out the necessary amount of research, especially in the field of fish stock assessment; and, secondly, the timely provision of complete fisheries statistics and associated biological data. Agreement on this aspect of fisheries management was reached at the Special NEAFC Meeting at the level of ministers and at the UN Stockholm Conference on the Human Environment. It is to be hoped that action to implement this agreement will soon be forthcoming.

Appendix 1

Working Groups Relevant to the Work of the Liaison Committee of ICES

Working Group for Data Collection and Processing in Fish Capture Research (Gear and Behaviour Committee)
Working Group for Standardization of Scientific Methods for Comparing Catching Performance of Different Fishing Gears (Gear and Behaviour Committee)
Working Group on Research on Sound and Vibrations in Relation to Fish Capture (Gear and Behaviour Committee)
Working Group on Research on Engineering Aspects of Fishing Gear, Vessels, and Equipment (Gear and Behaviour Committee)
Working Group on Fish Reactivity in Relation to Fish Capture (Gear and Behaviour Committee)
Working Group on Eventual Establishment of an ICES ADP System for Fishery Statistics (Statistics Committee)
North-East Arctic Fisheries Working Group (Demersal Fish (Northern) Committee)
North-Western Working Group (Demersal Fish (Northern) Committee)
North Sea Flatfish Working Group (Demersal Fish (Northern) Committee)
North Sea Roundfish Working Group (Demersal Fish (Northern) Committee)
Coalfish (Saithe) Working Group (Demersal Fish (Northern) Committee)
Working Group on Irish Sea Whiting Stocks (Demersal Fish (Northern) Committee)
Working Group on the Assessment of the Stocks of Hake (Demersal Fish (Northern) and (Southern) Committees)
Working Group on North Sea Herring Larval Surveys (Pelagic Fish (Northern) Committee)
Working Group on North Sea Young Herring Surveys (Pelagic Fish (Northern) Committee)
Atlanto-Scandian Herring Working Group (Pelagic Fish (Northern) Committee)
North Sea Herring Assessment Working Group (Pelagic Fish (Northern) Committee)

Working Group on Celtic Sea Herring Assessment (Pelagic Fish (Northern) Committee)
Working Group on the Bløden Tagging Experiment (Pelagic Fish (Northern) Committee)
Bluefin Tuna Working Group (Pelagic Fish (Southern) Committee)
Working Group on Assessment of *Pandalus* Stocks (Shellfish and Benthos Committee)
ICES/ICNAF Joint Working Party on North Atlantic Salmon
Joint ICES/ICNAF Working Group on Cod Stocks in the North Atlantic

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Report on Technical Session I

1. The Conference considered the problems of fisheries science and management against the setting of world fisheries changing at an increasingly fast pace. This places increasing stress on the need for adequate advice as the basis for effective action. It is becoming ever more essential that the correct decisions are made concerning the development and management of the world's fisheries.

2. Ideally this scientific advice should be based on a comprehensive understanding of the dynamics of the complete system in which the fish stocks and the fishery exist. Though a complete understanding of any natural phenomenon can never be reached, it is not necessary for decision makers to wait until the scientific community have completed their studies. Sufficient scientific understanding can often be attained for valuable management decisions to be taken. Recently there have been several examples of fisheries in which the scientific advice has advanced to the point at which decisions can be taken, such as the quotas recently set for many stocks in the northwest Atlantic.

3. It was therefore felt that the scientific task, in relation to the work of the Conference, was to identify the best ways in which existing scientific models, data and other scientific resources could be used to help decision makers. It was stressed that the kinds of decisions that needed to be taken, and the nature of the scientific advice and investigations, were different for fisheries in different stages of development. Good communications between scientists and decision makers are therefore essential, so that scientists know what is required, and decision makers understand what can be provided.

4. In the past advice by scientists to decision makers has sometimes been inappropriate and has often been misunderstood. In nearly all countries there is a problem of communication between managers and researchers, and between both of these groups and the fishermen. Hence, communication both ways becomes increasingly critical. If this is to be effective, clear definitions are essential as to what is meant in various countries by such terms as "management," "development," "rational use of resources," "over fishing," etc. Good communications should also lead to a clearer definition of the objectives of management.

5. In many countries production of food is the prime need; goals such as maximum sustained yield (MSY) from any one particular stock, or maximum economic yield (MEY) are remote. Some participants felt strongly that economic and social goals should be paramount. Others believed that these would never be greatly different from MSY, and in any event individual countries should handle economics each in its own way. Some participants expressed regret that the argument of which goal (maximum physical or maximum economic yield) was still being debated, since these cannot usually be achieved precisely in practice, nor are they greatly different in quantity in most instances.

6. The necessary scientific activities fall into two groups —the collection of statistical and other data which must be done for each particular fishery for which advice is being sought, and the more basic scientific investigations from which new ideas, concepts and techniques could be developed. Though these latter studies might in the first instance be made with reference to a particular fishery, the results would be expected to have wide applicability. They would presumably be carried out in a large, well-equipped research institution, which of course need not necessarily be located in developed countries. Laboratories in developing countries might be expected to make particularly valuable contributions from the study of the situations peculiar to them, such as the dynamics of fisheries in tropical areas. In the tropics, research methods usually must be modified because (for example) of a great variety of species in a single fishery, or the absence of satisfactory indicators of age, and the difficulties of tagging.

7. In discussing both data requirements and basic research, it was stressed that priorities would differ between different regions and fisheries. If advice is needed in relation to a single species fishery (e.g. the Peruvian anchoveta), more emphasis is likely to be desirable on such matters as collection of data on size composition, or the influence of parent abundance on numbers of progeny, than when advice is needed for a complex multi-species fishery (e.g. the trawl fishery in the Gulf of Thailand).

8. The volume and extent of the scientific studies also needed to be in proportion to the potential benefit. A larger and more valuable fishery justifies a larger and more detailed scientific programme.

Statistics and Other Basic Data

9. Whatever the type and magnitude of the fishery, there are certain types of data that must be collected. These include data of total catch, almost certainly broken down according to major species, area and time of capture, and type of gear a vessel used, and data of the input into the fishery, such as number and size of vessels. Despite resolutions and recommendations at almost every fishery meeting, the supply of these basic data remains, in respect of most fisheries, inadequate for the provision of good advice. Generally the cost of providing such data is small, and very much less than the likely benefits from better and more timely management decisions. It was stressed that the provision of such data was the responsibility of all those engaged in a fishery.

10. It was pointed out that in some fisheries, especially in developing countries, where operations are carried out by a large number of widely scattered fishermen, the cost of collecting comprehensive statistics was large, and the use of suitable sampling and survey schemes was desirable. The value of technical assistance in designing such

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schemes, and in advising on the collection of statistics in general, was stressed.

11. In most fisheries it is also essential to have some index of the abundance of the fish stocks. Often this may be obtained from the analysis of detailed catch and effort statistics. Surveys by research vessels, e.g. with trawls or acoustic gear, can also be used, and are especially valuable in the early developmental stages of a fishery. Survey results are likely to be more reliable than the results of the analysis of catch and effort statistics, especially when there are changes and developments in the type of gear used in the commercial fisheries. However, the operation of a special survey vessel can be expensive, and it is therefore important to determine which method of monitoring changes in abundance is most cost effective in any particular fishery. It was also pointed out that stock analysis from fishery statistics gives information about the exploitable part of the stock only. Biologists also often need to have data on the other parts of the stock, particularly of the abundance of year-classes before they enter the fishery, and for this research or survey vessels are essential.

12. A wide range of other types of information can also be collected, some of it relatively cheaply. These include data on the sizes or ages of the fish in the commercial catches, studies on the separation of different stocks, growth studies, etc. What should be collected in any given fishery will depend on the questions that are likely to be posed by the management agency. For example, if some control on the sizes of fish caught might be a practicable and productive method of management, then size composition data would be essential.

13. Once the data are collected, then interpretation, and the preparation of advice depend on the existence of some type of conceptual model. Existing models, e.g. those of Schaefer, Ricker, or Beverton and Holt, have enabled advice to be given and decisions taken, in respect of several important fisheries, but with the increasing intensity and complexity of modern fisheries, further research is important.

14. Though the Conference could not specify with any great precision the particular research topics which were most likely to prove useful for dealing with the fishery problems of the 1980s, the need was stressed for investigation of a series of alternative scientific approaches. Topics that were mentioned as likely to be especially useful, included the study of stabilization processes in populations, including the effect of fishery-induced changes in adult abundance on the strength of subsequent year-classes, the study of nonsteady-state situations, the effect of man-made changes in the environment, and the effects of exploitation on complex multi-species communities.

15. It was pointed out that environmental factors of many kinds often affect fish stocks and fisheries, and that the study of such effects could be valuable. Ways in which oceanographic and similar studies could be valuable included: (a) improved stock assessments by sorting our environmental effects from fishing effects, (b) improving the performance of the fishery, e.g. by indicating areas where fishing might be undertaken, or by allowing the build-up of cannery equipment in advance of a good salmon run, and (c) better management decisions, e.g. reducing catch quotas when a poor year-class recruits to the fishery.

16. Concern was expressed that the pressing need for research of immediate applicability might detract from necessary longer-term and basic programs. It was pointed out that when the currently expected 80–100 million tons of fish is being taken 15–25 years hence, new knowledge will be needed to increase aquatic productivity still further. Here general oceanographic research will play an important role.

17. In addition to research into purely biological situations, the need for research into the whole fishery situation was stressed. A fishery is a complex interaction of biological, economic, technological, and social factors, and models are needed to enable a decision maker to deal logically with those factors. The growing disciplines of system analysis and operational research can be used to study this situation.

18. Although it is desirable to carry out further research into methods of applying system analysis to fisheries, enough is already known to enable these approaches to be applied to present fishery problems, and their application can be fruitful, both in determining the most promising lines of scientific research, and in identifying appropriate management action. The Conference urged that systems management be applied to an existing or developing fishery, to demonstrate its utility.

19. It was frequently stressed that management action should not be postponed until research had identified the optimum long-term policy. Such action might be to ensure that no irreparable damage was done to the stocks or to the fishery by overexploitation, or the growth of excess capacity (precautionary management), or to provide information on which more precise assessments could be made (experimental management).

20. Several speakers stressed the need for trained personnel in less-developed countries. Local people should be trained for the local situation, so that they can modify techniques to meet local conditions and devise new ones when necessary.

21. Trained people are needed at all levels: fishermen, collectors of statistics, research scientists, and managers. It was noted that partnership arrangements had been established between some institutions in developing and developed countries whereby expertise is provided by senior staff members of the latter and training of the former, and that these had proved very successful.

Other Uses of the Ocean

22. Fishing is not man's only activity in the ocean. Increasingly other activities (waste disposal, oil-drilling, etc.) will have an impact on fish stocks and fisheries, and several speakers expressed concern that fisheries may be more threatened by pollution than by any other influence. However, this impact in no way reduces the need, within the fishery sector, to take appropriate management action to deal with the problems of overexploitation and excess capacity. The main responsibility of the fishery scientist in relation to other uses of the ocean, is to provide the policy makers with the right information so that appropriate

action is taken, outside the fishery sector, to minimize the harmful effects on fisheries of these other activities. A similarity of pollution and overexploitation was noted in that, in many situations, the urgent need is less for further research than for action which is known to be needed on the basis of information already available to be taken to control pollution or reduce fishing. Equally, there are other situations when further research may be necessary before action can be contemplated.

23. Several references were made to the heavy metal problem. The need was stressed for a better public understanding of the nature, source, and effects of heavy metals, and for a properly balanced reaction to these problems.

24. Fisheries management should be considered within a wide context, involving socioeconomic goals as well as yield; in effect this needs a "bio-socioeconomic" approach. The need for this has been accentuated by the increasing multipurpose use of the ocean, indeed the concept of "fisheries management," should be broadened to "ocean management."

25. As management becomes more complex, a comprehensive approach to establishing objectives, alternatives, evaluation of these alternatives, and programs of action become increasingly important. Managers should be given a set of alternatives by the scientists, with the biological (and if possible other), consequences of each set forth.

26. It was also stressed that the proper conservation and management of fishery resources was of very wide concern, as part of the even more general concern for the proper use of the ocean, natural resources, and the human environment as a whole. While the immediate responsibility belongs to those currently engaged in the fishery, the world community as a whole, and the countries adjacent to the resource in particular (whether or not they are currently engaged in the fishery), are also concerned in ensuring that the resources are properly managed.

FAO Technical Conference on Fishery Management and Development

TECHNICAL SESSION II

Economic and Institutional Aspects in the Management and Development of Fisheries

CHAIRMAN: K. LØKKEGAARD, DENMARK

Economics of Fishery Management[1]

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In an unmanaged fishery the costs of catching a unit weight of fish will tend to rise until they are equal to the value of the catch. There is likely to be an excessive amount of fishing which adds to the costs, but adds little or nothing to the total catch, and may even decrease it. In practice the amount of fishing will often exceed the equilibrium, due to delays in reacting to falling catch rates, year-to-year fluctuation in the fishery, etc. The labor and capital engaged in fishing is often relatively immobile, and once excess capacity has developed it is not easily reduced without special measures.

A number of different measures are available to control both the amount of fishing and the sizes of the fish caught. These are outlined, and the advantages and disadvantages briefly discussed. Several of the methods of controlling the amount of fishing tend to add to unit costs, and therefore offer little long-term benefits. These benefits can only be assured by control of the total capacity engaged in a fishery, such as through allocation of shares to individual countries in an international fishery, or by license limitation in a national fishery.

En l'absence d'aménagement des pêches, le coût de capture du poisson par unité de poids tend à s'élever jusqu'à ce qu'il devienne égal à la valeur de la capture. Il est d'ailleurs probable en pareil cas que la pêche est excessive, accroissant les coûts, mais peu ou pas les captures totales, qu'elle réduit même peut-être. En réalité, l'intensité de la pêche dépasse souvent cet état d'équilibre en raison du temps de réaction à la baisse des taux de capture, des fluctuations annuelles de la pêche, etc. La main-d'oeuvre et les capitaux engagés dans la pêche sont souvent relativement immobiles et une fois que la capacité est excédentaire elle ne se laisse pas facilement réduire sans mesures spéciales.

Diverses mesures permettent de réglementer tant l'intensité de la pêche que la taille des poissons capturés. Ces mesures, avec leurs avantages et leurs inconvénients, sont brièvement examinées. Plusieurs des méthodes de réglementation de l'intensité de la pêche ont tendance à accroître les coûts unitaires et n'offrent donc guère d'avantage à long terme. De tels avantages ne peuvent être garantis que par la réglementation de la capacité totale des armements qui participent à une pêche, par l'attribution de contingents à chaque pays dans le cas d'une pêche internationale ou par l'octroi de permis dans celui d'une pêche nationale.

En unas pesquerías desorganizadas, los costos de captura de una unidad de peso tenderán a aumentar hasta igualar el valor de todo lo pescado. Es probable que una intensificación excesiva de la actividad pesquera haga aumentar los costos, por más que haga aumentar poco o nada la captura total, si es que no la hace disminuir. En la práctica, la intensidad de las actividades pesqueras superará con frecuencia este equilibrio al no reaccionar a tiempo a la disminución de la captura, por la fluctuación de las actividades pesqueras de un año para otro, etc. La mano de obra y el capital que participan en las pesquerías pueden ser relativamente constantes, y una vez que se ha rebasado el límite de capacidad, no es fácil volverlo a reducir sin adoptar medidas especiales.

Pueden adoptarse diversas medidas para regular las actividades pesqueras y la talla del pescado. Aquí se esbozan esas medidas y se examinan brevemente sus ventajas y desventajas. Algunos de los métodos de regulación de las actividades pesqueras tiendena hacer subir los costos unitarios, por lo que reportan pocos beneficios a largo plazo. Esos beneficios pueden asegurarse únicamente mediante una regulación de la capacidad total en la pesquería, adjudicando a determinados países participaciones en una pesquería internacional o limitando las licencias o autorizaciones en una pesquería nacional.

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FISHING is an economic activity. In some places it is the dominant economic activity for whole towns, regions, or even countries (for example, Iceland). Any action to develop or manage a fishery can have important economic consequences, and should be taken in full awareness of these, and of the general economic problems involved. The economic problems of development of fisheries are in general similar to those of development in any other field — need for capital, market expansion, etc., and are thus normally familiar to government and industry. On the other hand, the problems of management are to a large extent unique to fisheries, though having some elements in common with other industries based on renewable natural resources such as forestry. Some resource management aspects, for example that by increasing the number of boats in a fishery not only will the catch per boat decrease, but also a constant or even declining total catch can result, may come as a surprise to those unfamiliar with the biological aspects of fisheries.

Because fishery management must be based on a sound understanding of the dynamics of the fish stocks, and of the effects on the abundance of the fish and on the total catch of changes in the pattern and intensity of fishing, management studies have been dominated by biological scientists. This is perhaps unfortunate since the objectives of fishery management are essentially economic, and the effects of management action have repercussions on important economic magnitudes such as employment, income, and the welfare of fishing communities generally. Furthermore, the dominance of the biologists in early fishery management studies has sometimes obscured the fact that the greatest benefits of management action are generally in cost reduction rather than through increased production. In many fish stocks, for example, the total catch will not be changed more than perhaps 10–15% whether there is management action or not, whereas appropriate action could reduce costs by 50% or even more. For these reasons the present review concentrates on the economic aspects of management, paying little attention to development except to the extent that appropriate action in the developmental phase of a fishery, e.g. a brake on extremely rapid development in the absence of estimates of the potential of the resource, can minimize later social or economic problems of management.

Economic Implications of Biological Assessments

The essential background to the study of the economics of fishery management is the biologically-determined curve relating the amount of fishing to the size of the catch. The nature of this, and the ways in which the curve for a particular fishery may be determined, have been discussed in the first section of this meeting. Though there are differences in detail between various stocks — particularly between animals such as whales where any appreciable reduction in adult stock will lead to a reduction in the number of young animals entering the fishery, and others such as plaice with very high fecundity such that even a very small adult stock can produce enough eggs to maintain the stock — the general features are the same.

At first, increasing amounts of fishing will bring about almost proportional increases in the catch, but soon the rate of increase in catch steadily falls below the rate of increase in the amount of fishing. At some point increases in fishing give negligible further increases in total catch. It may be that beyond this point the catches may continue to increase, if at an extremely slow rate, so that, for example, doubling the amount of fishing might give a 5% increase in catch. On the other hand, it is quite likely that increases in fishing beyond some point will actually decrease the total catch, possibly catastrophically (e.g. whales), or only to a small or moderate extent (e.g. plaice). In this latter case there is a particular amount of fishing (which may depend on the range of sizes caught) which will give the greatest yield over a period (commonly referred to as the maximum sustained yield).

These curves, relating volume of catch to the amount of fishing, can readily be converted into economic terms. For a reasonable first approximation, the value of the catch for any one stock can be taken as proportional to its volume, and (other things being equal) the costs as proportional to the amount of fishing — though the effect of several types of management action is often to alter the cost of a given amount of fishing.

Marginal Cost and Marginal Revenue

The concepts of marginal cost and marginal revenue are also important to the study of the economics of management. Optimum economic exploitation of the resource requires that fishing effort be increased up to the point at which marginal cost equals marginal revenue, i.e. the point where the revenue derived from an extra unit of fish landed is equal to the incremental cost of catching it. It is clear that if marginal revenue exceeds marginal cost it will pay to expand effort; or conversely, to decrease it if the costs of catching an extra unit of fish exceed the extra revenue obtained from its sale.

Since a fishery is a (finite) common-property resource, there is a divergence between marginal private costs and revenues and marginal social costs and revenues. This divergence arises from the fact that after a fairly early stage in a fishery's development, any additional effort by one fisherman or enterprise will adversely affect other fishermen. The marginal production to society of an extra vessel will always be less than the catch of that vessel, because its activities will reduce the stock of fish and therefore to some extent the catches of other vessels. The competitive nature of common-property resource exploitation results, therefore, in effort being pushed beyond the point of coincidence of marginal cost and marginal revenue to the point where average cost equals average revenue, i.e. the value of the catch is equal to the cost of catching it (including a reasonable return on invested capital).

In the long term, a normal fishery might be expected to reach equilibrium around such a break-even point, and the enterprise or individual fisherman will be expected to get approximately the same return on his capital or labor as he would from feasible, alternative employment. This equilibrium will certainly be at a higher level of fishing than would occur if the fishery were under single ownership and where the marginal return from a unit of effort would be equal to the cost of exerting the additional effort. This equilibrium level may also be above that giving the maximum sustainable yield, so that management measures to reduce the amount of fishing may increase the gross value of the catch (sometimes considerably, e.g. whales), and can always increase the net economic returns from the fishery. Whether or not such economic benefits are in fact realized will depend on the form of the management regime and the degree to which it may interfere with efficiency.

Apart from stocks for which management may be needed to maintain the total catch at a reasonably high level — and although these stocks include some striking examples, such as whales, they are in total only a small proportion of the total world fisheries — this analysis of the long-term equilibrium situation might suggest that the need for management is not in general very pressing. The prizes offered are a possible small increase in total catch and an improvement in the economic performance of an industry which would be expected to give no worse (if no better) returns that available alternatives.

However, this long-term equilibrium state is seldom attained in practice and there are few, if any, major unmanaged fisheries that are at all close to this break-even equilibrium. This is partly due to the fact that many fisheries are exploited by different types of vessels and by vessels from countries having different cost conditions. Thus, the equality of marginal cost and marginal revenue — the condition for optimum economic performance — will be obtained at different levels of output for different units of the fishery. Thus, even though some producers may be in economic difficulties, low cost producers will still be able to expand their fishing, incidentally causing further distress to other fishermen.

Failure to reach any form of equilibrium, however unsatisfactory, is due also to the long time required to reach such a condition, which even in a period without great technological change would be at least comparable to the average working life of a vessel. This is of the order of a couple of decades, whereas the pattern of many if not most fisheries has changed completely in a much shorter time. Further, the pace of change has increased recently and several fisheries have developed from virtually nothing to a state where the resource is fully exploited in a very few years.

As a result, only in few fisheries is the amount of fishing presently appropriate to the achievement of long-term equilibrium, with net economic return approximately equal to that prevailing outside fisheries. In fact, there are many instances where the amount of fishing is considerably larger than this, and therefore to an even greater extent in excess of that required for the optimum economic return. The main reason for this is the time lag after which many factors take effect.

TENDENCY TOWARD OVERCAPACITY

The decision by a businessman to invest in a new vessel, or by a fisherman to enter a fishery, is usually made more on the basis of the success of fishing in the recent past rather than after a careful evaluation of the prospects in the future. Thus the decision, in say 1973, to build a boat to come into operation in 1975, with a working life likely to stretch well into the 1980s, is likely to be based mainly on the events in 1971 and 1972. Furthermore, the effects of the secular decline in the abundance of the fish stocks under the pressure of increasing fishing effort are from time to time masked by good year-classes. Investments made as a result of the good results produced by these good year-classes are frequently unjustifiable on any long-run trend in the productivity of the fishery.

Similarly, technological innovation often leads to overcapacity in a fishery. The early stages of the development of a new fishery, or of the application of a new technique in an existing fishery, frequently offer rates of return on investment that are not often met elsewhere. For example, when power-block purse seining was first introduced into the tuna fisheries of the eastern Pacific and into the herring fisheries of the North Atlantic, the new vessels built to take advantage of this new technique could pay for themselves in little more than a couple of years' fishing.

With such good results in the past it is not surprising that new vessels continue to be built and new fishermen enter a fishery even when it is highly improbable that the same successes will be repeated in the same fishery in the future. However, once in the fishery the new vessel or fisherman or business unit tends to be trapped. The decision whether or not to leave it depends less on the levels of return on investment or of wage rates in the economy as a whole than on those in the relatively narrow range of feasible alternative employments.

A classical example of this situation is the British North Sea trawl fishery in the inter-war period. Immediately after the 4 years' respite from fishing occasioned by the first world war, fish stocks and catch rates were high, despite the introduction into the fishery of large numbers of trawlers built during the war for minesweeping and similar naval duties; these good conditions gave impetus to a further burst of new vessel construction. Thus, by 1922 when catch rates had declined to the pre-war level or below, not only was the size of the trawl fleet two or three times that required to harvest the North Sea demersal stocks most efficiently (i.e. giving the maximum net economic return), it was also grossly in excess of that compatible with the achievement of the long-term equilibrium. In other words, there were so many boats that the catch per boat had been reduced well below that which would cover all costs and leave a return on investment comparable with alternatives outside fishing. However, the trawlers were built, and except for minor fisheries on the British west coast (which were in a similar situation), they had no alternative use. Low though the catch rates were, on the average they were high enough to cover the basic running costs, so that the vessels remained in use.

The rate at which fisheries are now developing, which is such that a stock can become heavily exploited within a few years of their beginning, makes this state of disequilibrium common. Thus, in the absence of appropriate management a fishery will tend to a state where the value of the catch covers little more than the running and maintenance costs, and provides no surplus for depreciation or return on capital invested. The fact that many important fishing nations have resorted to subsidy to maintain the fishing capacity of their fleets is evidence of this tendency.

Once vessels or shore facilities have been constructed, the extent to which this trap can be escaped is limited by the restricted degree of mobility of the investment. Up to the present there has often been the opportunity for diversion to alternative fisheries, particularly for the fleets of large long-range vessels which are the commonest agents of rapid increases in fishing effort on an individual stock. Lack of management (or management rules that do not limit the total capacity of the fishing fleet, e.g. overall quotas set by IATTC for yellowfin tuna in the eastern tropical Pacific) actively encourages development of fisheries on hitherto underexploited stocks, and results in an increase in the total catch. For example, although the California-based tuna fleet is undoubtedly too large in relation to the local resources (the total carrying capacity is now not much less than the annual quota), this overcapacity has encouraged expansion both further westward into the Pacific and into the Atlantic, with a resultant increase in catches.

However, this process cannot be continued indefinitely. A limit is set by the availability of alternative underexploited stocks suitable for harvesting by the existing vessels. As has been pointed out elsewhere in this Conference, the number of such stocks is being rapidly reduced, and in the near future the opportunities for minimizing the economic distress from overexpansion will disappear.

EMPLOYMENT AND INCOME

The preceding analysis has considered mainly the economic effects in terms of return (or lack of return) on investment; the effects on employment and on the social and financial condition of the fishermen are similar. The skills and experience of fishermen are not, in general, readily applicable outside fishing, and movement of labor from fishing to other employment is not easy. Nevertheless, excessive employment in the industry is almost certain to have a depressing effect on wage levels.

Overemployment in the fishing industry does not often result from direct overexpansion, although there are some notable examples of this, such as the Peruvian anchovy fishery. More frequently an excess in the number of fishermen arises as a result of technical innovation. For example, the introduction of outboard motors can double the fishing power of the boats or canoes being used, and the first fishermen to use them will initially double their catch. However, if the resource is close to being fully exploited, and all fishermen motorize their canoes, the total catch will increase very little, and can now be harvested by half the number of vessels and fishermen. Unless some fishermen leave the fishery no benefit will have been derived from the innovation — and in fact the last state will be worse than the first since the costs of the motors will now have to be paid.

Possible Benefits from Management

The preceding sections have discussed the serious economic and social problems that can arise in the absence of effective management, and which are likely to intensify in the near future with the reduction in the number of alternative underexploited resources. The effects of management can also be considered in terms of the benefits that might be attained, especially in increased net economic returns. These can be very considerable, though few explicit calculations of the possible benefits have been made. One assessment was made of the reduction in costs possible in the cod fishery in the North Atlantic (ICNAF 1968). Under the conditions of the fishery existing in 1965, it was estimated that a reduction of 10–20% in the total fishing effort would be possible without affecting the total yield. In principle, such a reduction in effort should result in an equivalent reduction in costs, and the ICNAF Working Group estimated that the possible savings amounted to $50–100 million (US) per year. Since 1965, the amount of fishing in fact has increased (although in 1972 ICNAF took action through catch quotas to limit the amount of fishing on most of the important cod stocks in the Northwest Atlantic), thus the savings now possible are considerably greater.

Similar savings are possible in many other fisheries, both national and international. For example, a panel of experts assembled by FAO to advise the Peruvian Government estimated that in the Peruvian anchoveta fishery the possible saving through the reduction of excess capacity in the fleet and in the processing plants was some $50 million (US) a year (Anon. 1970). The possible savings as a proportion of the total costs may be even greater in other fisheries. That for salmon in the Pacific is an extreme one, in which the harvest could probably be taken with no more than a quarter of the present costs.

These very large benefits generally arise from lower costs rather than from increases in the value of the catch; in most fisheries the latter benefit is not much more than a few percent of the total, although in aggregate such benefits are not inconsiderable. There are, however, some fisheries in which the potential increase in catch is very great. Properly managed, the stocks of the major species of baleen whales in the Antarctic could have provided an annual sustained yield of some 6000 blue whales, 20,000 fin whales, and several thousand sei whales, compared with the present catch limits of only a few thousand fin and sei whales. Catching of the blue whales is prohibited and this prohibition will have to continue for many years to allow the stocks to rebuild. Even the measures taken by the International Whaling Commission, inadequate though they were, produced increases in catches of the fin and sei whales compared with those that would have been taken in the absence of any measures. These extra catches are estimated to be worth $120 million (US) (Gulland 1966).

PROBLEMS IN LIMITING FISHING EFFORT

These estimates of the possible benefits from proper management, worth overall hundreds of million of dollars per year, in one respect are only notional. To a large extent they represent the savings that could be achieved if the costs could be reduced in proportion to the reduction in fishing effort that is possible without affecting the total catch. The attainment of this benefit depends not only on reaching agreement to make the necessary reduction in the amount of fishing, but also on actually reducing costs in proportion to the reduction in fishing.

Neither of these is easy to achieve in practice. Numerous international commissions, although readily agreeing that limitation of the amount of fishing on one or more stocks within their areas of competence is desirable, are finding it very difficult in practice to reach agreement on how such limitation should be implemented. For fisheries lying wholly within a single national jurisdiction, steps to limit the amount of fishing have been implemented somewhat more frequently, but usually the methods that have been found acceptable achieve the necessary reduction in the effective amount of fishing (fishing mortality) by reducing the efficiency of the individual fishing unit. An outstanding example is the salmon fishery of western North America, where there are strict controls both on the types of gear used and the times and places when they can be used, although (except recently in British Columbia) the number of fishermen and fishing vessels has not been controlled. Such regulations give little or no opportunity for reducing costs.

A full reduction in costs can be achieved only by taking the surplus capacity out of the fishery completely and employing the resources of men and capital in some more productive operation, possibly outside fisheries. As already discussed, this diversion is not easy once the fishery has developed and capacity has built up to an undesirably high level. Much of the equipment cannot be used outside fishing, or perhaps even outside the particular fishery suffering from overcapacity, and the redeployment of the fishermen may require costly compensation and retraining programs. The maximum economic benefits from management can therefore only come by taking appropriate action early in the development of the fishery, before the excess capacity has been established.

NEED FOR EARLY ACTION

Early action has other advantages. It is much easier to persuade people not to do something they are at present only contemplating than to stop doing something in which they are already engaged. Thus, in principle it should be easier to reach agreement on action to limit the amount of fishing early in the development of a fishery rather than later, whether the agreement is between countries or within a single national fishery. It may be noted, however, that in the past fishermen have been unwilling to accept the existence of overcapacity until faced with the direct evidence of drastically falling incomes. Also, scientists may not find it easy to produce the evidence of the effect of fishing until development is well advanced. Nevertheless, the constantly recurring problems associated with overcapacity have made all those concerned with fisheries more ready to accept the need for limitation in a given fishery without waiting for conclusive evidence of overcapacity and its harmful effects in that particular fishery. Meanwhile, scientists are developing techniques for the provision of earlier advice on the magnitude of the resource, and the advisable level of catch from it.

Economic and Other Objectives

Although the preceding sections have shown that some of the biggest potential benefits from management come from the economic effects — particularly the reduction of excess costs — it has sometimes been suggested that economic aspects should not receive high priority when considering management problems. Two reasons have been put forward for this — that the pressing need in the world is not to make money but to provide food for the hungry, and that even if economic objectives were accepted, differences in economic conditions would make impossible the definition of a unique optimum for the pattern of exploitation of the resource. Both these arguments are misleading.

MAXIMIZING FOOD SUPPLY

Maximizing the food supply does not necessarily imply maximizing the harvest from any particular stock of fish, nor that the inputs used to take that harvest cannot be used in any other way to increase total food supplies. There is economic waste in employing an extra 10–20% of fishing effort to obtain the ultimate 1 or 2% of the maximum possible yield of fish, as well as in employing relatively large inputs to achieve a small additional amount of food from a stock which is already heavily fished. Instead, this effort should be diverted to another stock which is less than fully exploited, even at the risk of reducing the catches of individual fishermen. Alternatively, the additional resources could be used to increase food production outside fish catching — possibly, for example, in aquaculture. Although alternatives of this kind are fewer than those available when the objective is beneficial economic activity of any kind, some useful alternative is almost certain to exist. In other words, the greatest food production will not be obtained by attempting to take the maximum sustained yield in weight from individual heavily exploited fish stocks, but rather by harvesting these stocks at a level which is probably not much greater than that which yields the greatest net economic return, using the resources of material and manpower thereby saved to increase food production elsewhere.

MAXIMUM SUSTAINABLE YIELD

Although the uniquely definable position of the maximum sustainable yield has advantages in theoretical discussions, it has often been pointed out that the best should not be the enemy of the good, and the practical problems are not the definition of the unique optimum as the ultimate objective, but the identification of action that will improve matters. In fact, it is doubtful whether the maximum sustainable yield can in reality provide such a unique and readily definable objective as is sometimes implied. Very often there are great technical difficulties in establishing with any accuracy the position of the maximum sustainable yield (rather than the maximum yield per recruit) for a single stock. Even when the maximum sustainable yield can be estimated closely as so many thousand tons, and it has been determined that a given, moderately intensive level of fishing will give a sustained yield very little different from the maximum sustainable yield, it can be difficult for biologists to assert with full confidence that increases in fishing effort beyond that level might not give some increase in the sustained yield. If more than one species of fish occurs in an area there will probably be biological interactions among them, such that the yield from one stock will depend on the degree of exploitation of the others; thus, there will not be a unique maximum for the total yield.

MAXIMUM NET ECONOMIC RETURN

The position of the maximum net economic return is also clearly not unique, but depends on the cost of harvesting and the value of fish; the lower the cost or the greater the value, the greater will be the advantage of increasing the amount of fishing to add a few extra percent to the total catch, thus approaching more closely the maximum sustained yield. On the other hand, given the characteristic flat-topped shape of the yield curve (or its revenue equivalent), it is easier to determine if fishing effort has exceeded the point of maximum economic return rather than the point of maximum physical yield. At the point where the maximum economic yield occurs, the yield curve (or its revenue equivalent) is rising relatively steeply and it is reasonably easy to determine whether there is too much fishing or too little. It is, however, more difficult to determine precisely which point on the flat top of the yield curve is the maximum. Since the yield will change little over a very wide range of fishing effort, given the fact that most stocks are subject to natural fluctuations, it will be impossible to say with any certainty that the fishing effort is just sufficient to take the maximum catch, or whether some increase (or decrease) is necessary to achieve the absolute maximum. Thus, if the objective is to set the amount of fishing at the level of the maximum sustainable yield, it is often very difficult to determine the action needed to achieve it. It is usually much easier to determine the action needed to increase the economic returns.

BROAD OBJECTIVES

The effect of differences in economic conditions and objectives should not be exaggerated, even if (as is intended here) the scope of the economic objectives is widened to include fairly general social considerations (for example, the maintenance of a high level of employment among fishermen) rather than restricting them to the narrow sense of maximizing net profits. Undoubtedly, those countries with great need of protein but little alternative supply will consider a higher rate of fishing more desirable than countries which are more interested in general economic returns and which have many alternative uses of capital and manpower. Nevertheless, for a given stock the optimum values of the amount of fishing for different national objectives will all be less than that value which gives the maximum sustained yield (MSY) and probably will be grouped quite closely together at some distance from the MSY point. In a typical overexploited, unmanaged, intensive fishery in which the amount of fishing is greater than the optimum on any criterion (and quite possibly beyond the MSY point) the practical need is not to reach agreement on the precise optimum position, but to take action to reduce the amount of fishing, at least to the highest of the various national optimum levels. Reduction to this level will be to the advantage of all parties. Further reduction would give some benefit to the fishery as a whole, but at some costs to those with either the greatest demand for fish or the lowest costs of harvesting. Thus, in most practical situations it is possible to identify action that can be taken which will be of general benefit, even when it is difficult or impossible to identify the optimum position that should be attained at the end of a series of management actions.

Implementation of Management: Immediate Problems

The biological characteristics of the fish stock and the fishery, in the form of the relations between the total catch (or catch per unit of effort) and the total amount of fishing (and its pattern), determine whether management action is desirable. Such biological relations will establish the effects on catches of limiting the amount of fishing or of controlling the kinds or sizes of fish caught; however, these limitations can be achieved by a range of different types of management actions, each of which may have quite different economic and social effects, both immediate and long-term.

CONTROL OF THE SIZES CAUGHT

Actions to control the sizes of fish caught generally have no unexpected economic implications. Measures such as control of the mesh sizes in trawls, or limits to the sizes of fish that can be landed or sold, allow fishermen to carry on their activities in virtually the same way as before regulations were introduced, except for modifications to their gear or changes in the proportion of their catch that they are permitted to land. Costs will be little affected, particularly if time is allowed to use up existing supplies of nets with smaller mesh sizes, for example. Moreover, if the scientific assessments are correct and the measures have been properly chosen, the value of the catch will be increased marginally, possibly after a transitional period during which, for example, the small fish released by the larger mesh sizes are growing to a size at which they will be retained by the larger meshes. Since such measures should make fishing more profitable, without additional management action the long-term effect is to attract further capacity into the fishery, and hence to reduce profitability back to the original level. Therefore, such measures, while economically attractive in the short run, give no assurance of long-term economic benefit.

Other measures, which control the types of fish caught, may have more significant economic or social consequences. Closure of nursery grounds or the banning of fishing on spawning or prespawning concentrations, which may be well justified on biological grounds in view of the ultimately beneficial effect on the total yield, can have serious implications for particular groups of fishermen. Since the effects may be quite different for different groups of fishermen depending upon where, when and how they fish, the political and social consequences of such prohibitions can be as important in determining action as the purely biological assessments.

Such social considerations have been particularly obvious in the case of salmon, in both the Pacific and the Atlantic. The salmon may be harvested either on their feeding grounds at sea or on their return to their parent stream. The point at which the greatest yield may be taken depends on the balance between growth and loss rates. In the Pacific, taking the ocean life as a whole, this balance is such that the greatest yield is taken on return to the rivers, and there is general agreement (at least for the eastern side) not to harvest salmon on the high seas. This agreement also facilitates the detailed management of individual stocks to maintain the spawning population at the optimum level. In the Atlantic, the group of larger fish caught at Greenland would probably not grow enough before returning to their parent stream to balance the losses occurring en route, and the balance of present evidence is that the total weight caught is increased by the current catches at Greenland (see reports of the ICES/ICNAF Working Party on North Atlantic salmon). The measures which have been recommended by ICNAF to restrict the Greenland catches are therefore based less on biological grounds than on economic, political and social reasons. For example, the contribution to the national economy of a salmon caught in a sports fishery may be several times that of one caught in a commercial fishery. Moreover, the political pressure of sports fishermen against the ocean fishery is very considerable.

This political pressure and the clear differences in interest between the various groups, have highlighted the salmon conflicts in both oceans, but similar conflicts occur in many other fisheries where the fish can be harvested in several stages in their life history. The problems are less of optimizing the fishery as a whole — whether in terms of physical yield, or economic returns — than of maintaining the balance between the different groups of fishermen. For example, the important Arcto-Norwegian cod stocks from about 4 years old onward, are harvested by trawls, and, when adult (from 10 years old), by a variety of other gears on the spawning grounds. A further increase in trawl mesh size above that currently in force would probably increase the total yield and would certainly benefit the other gears (used by Norwegian fishermen) catching the big fish, but at some cost to the trawl fisheries (principally of the USSR and U.K.).

Control of the Amount of Fishing

Although measures to control the sizes of fish caught can introduce serious problems of conflict of interests among different groups of fishermen, within any particular group the problems of introducing such measures are not great. If the use of a larger mesh size is in the long-term interest of a group of fishermen, they can change to the larger size without significantly noticeable effect on their fishing practices. In particular, the efficiency of their operations will not be affected. This is not true of measures to control the total amount of fishing. Most measures will have great effects on the efficiency of fishing, in both the short-term and long-term. Many measures (including some that are the easiest to introduce) will reduce operational efficiency, and this reduction may be nearly as great as the reduction in the amount of fishing, so that the total cost is little affected. Since some of the greatest potential benefits of management lie in the possible reductions in costs, such measures are self-defeating.

The problems involved, and the effects on efficiency or costs, may be examined by considering the possible measures in detail. The regulations that can be used to control the amount of fishing include: limits on the type of gear that can be used; closed areas; closed seasons; a limit on the total catch; a limit on the total fishing effort, e.g. number of days fishing; a limit on the capacity of the fleet(s); a tax, or substantial license fee.

These may be used singly or in combination, and there can be some overlapping or interrelation between measures — for example, a catch quota is often enforced by starting a closed season from the date on which the quota is expected to be reached. Except for taxes or license fees, the measures listed above are equally applicable to an international fishery or to one lying wholly within the jurisdiction of a single country.

Controlling the amount of fishing by means of limitations on the type of gear is economically unjustifiable, and ideally the most efficient gear should be used. Nevertheless, such regulations are often used in national fisheries, usually on the grounds that a certain type of gear is too destructive. This argument may be justified when the gear is indiscriminate in its action (e.g. dynamite) and catches or kills sizes or kinds of fish that need to be protected. In such cases, the regulation should be based on the need to protect these fish, e.g. to allow the small fish to grow. Where a modern, more effective gear can be used to take the same classes of fish as other, perhaps traditional gears, the prohibition of its use will reduce the potential net economic return from the fishery, but may minimize social disturbances. For example, monofilament nylon gillnets are less visible to the fish and may catch twice as much, or more, than standard gillnets. The same catch could then be taken with half as many nets, and, in principle, approximately half the cost; in an ideal world the use of such nets should be permitted, if not encouraged, to improve the economic condition of the fishery. However, if the stock concerned is fully exploited there will only be a benefit if half the fishermen leave the fishery and find alternative employment. This may be difficult, even though it would be worthwhile to subsidize those displaced. In such cases prohibition of the more effective types of gear, though an admission of the failure to achieve optimum management, might at least have some benefit insofar as further increases in fishing effort might actually decrease the total catch.

Closed areas are a common, and often effective, method of protecting certain classes of fish, e.g. small fish in a nursery area. They are much less useful as controls on the total amount of fishing, since they are only effective to the extent that vessels have to leave the more productive areas, and go to grounds with less abundant stocks. This is just another method of reducing the efficiency of the fishery, and incurs the same objections as controls on the type of gear used.

Control of the amount of fishing by a closed season is very similar in its effect on fishing effort to control by a single unallocated quota of catch. In each case fishing is allowed freely up to a certain date, and is prohibited thereafter (possibly with some minor exceptions). The closing date may be established at the beginning of the season, or as the season progresses, on the basis of the cumulative catches taken or the effort expended.

The immediate economic effects of these measures are generally beneficial. The value of the catch may be slightly reduced, because of increased storage costs incurred by having the catch concentrated in (say) 8 months, rather than spread through the year, but the savings in costs will be large. Certainly, the operating costs will be reduced approximately in proportion to the reduction in the season (though there may be increased costs through the natural tendency of fishermen to have the maintenance and overhaul done in the closed season, which may lead to congestion in the yards if the closed season is short). If there are alternative uses of the vessels in the closed season, the overhead costs, including depreciation, can be shared with these alternative uses, and the proportion of these costs attributable to the regulated fishery can also be reduced more or less in proportion to the reduction in the open season.

In the short run, therefore, a closed season or a general overall catch quota can limit the amount of fishing and still permit the efficiency of the fishery to be maintained. Indeed, if there are marked seasonal variations in the availability of fish, and the closed season is set at a time when catch rates are low, there may even be an increase in efficiency. Thus, these regulations may at first allow virtually the full economic benefits of management to be attained. This means that the fishery will be highly profitable, and without additional restriction there will be an influx of new vessels into the fishery. If the total amount of fishing is to be maintained at the desired moderate level, the season will have to be shortened, in the case of quotas shortened automatically, as the permitted level of catch or effort is reached progressively earlier.

This shortening in the season has been observed in most fisheries controlled by a catch quota, e.g. Antarctic whales, Pacific halibut, and more recently the yellowfin tuna fishery in the eastern Pacific, where the closing date has been progressively advanced (from June 27, in 1967 to March 5, in 1972). As the proportion of the year in which fishing is allowed becomes shorter, the fishery becomes progressively less efficient, more and more capital becoming tied up in expensive equipment that lies idle for most of the year. Without control over entry the season shortens and inefficiency increases until the potential savings through reduced effort and reduced total costs have been swallowed up by increased overheads.

CONTROLLING EXCESS CAPACITY

In international fisheries, the commonest method of tackling this problem of increasing capacity is the allocation of shares in the total quota to individual countries. In itself this is not a complete solution, since it merely pushes the control of the excess capacity back to individual countries. However, solutions (e.g. by license fees or direct control of fleet capacity) are more easily found at the country level, particularly since different solutions can be found by each country and they can be adjusted to the particular interest of the country concerned (cheap fish, high employment among fishermen, maximum net economic returns, etc.). Country quotas were emphasized by the ICNAF Bio-economics Working Group (ICNAF 1967) as the best method whereby the greatest economic benefits could be obtained in a fishery exploited by a range of countries with very varied interests. They have since been adopted by ICNAF for a number of important fisheries for herring, cod, and other species. The achievements of ICNAF, and earlier of IWC in the Antarctic whale fishery, in which the countries were fewer but equally varied in their economic interests, have shown that the considerable obstacles in reaching agreement on how the total quota should be divided can be overcome.

Individual countries have a number of methods open to them with which to control the national fishery to the desired level. The same techniques of closed seasons, quotas, etc., that can be used internationally can equally well be applied at the national level, with the same advantages or disadvantages. As already noted, where the fishery is managed under a system of country allocations or quotas, individual countries can adopt different methods of ensuring that their fishermen catch no more (and if possible no less) than their allocation. Thus, one country with constitutional or other objections to limiting entry can adopt a single-quota system, closing its fishery when the quota is approached, while another may allocate shares of its national quota to individual companies, fishermen or groups of fishermen.

In principle, the latter system should allow each chosen group to take its share in the most efficient manner, i.e. minimizing the cost of harvesting and maximizing the value of the product, bearing in mind the likelihood that the price received is a function of the season of capture, size of fish, etc. The system also involves some degree of licensing and limitation of entry, which along with potential benefits entails many of the problems related to the allocation of national quotas in an international fishery, particularly the question of deciding the size of individual shares.

National governments have one major advantage over international bodies in allocating shares, and that is the ultimate authority over the participants. To some extent this power is illusory, since the political realities are often such that no management scheme can be introduced against the wishes of any significant group of fishermen, and many theoretically sound schemes have foundered in the face of opposition (often ill informed) of particular groups — sport fishermen often being among the worst offenders. In practice, the real advantage possessed by a national government lies in its ability to use licenses or other financial measures to determine allocations; in principle, such measures could presumably also be introduced, subject to general agreement, in an international fishery, but this does not appear a practical possibility in the near future. In the long term such methods of limiting entry should be so designed that licenses are only available by purchase, at some substantial sum, either from the government or from existing license holders. The costs of obtaining a license should be sufficiently high to limit new entrants to the number required to maintain the capacity of the fleet at the optimum level. Such schemes have been introduced or are under active consideration in a number of fisheries, for example, British Columbian salmon and west Australian rock lobster, usually with an interim phasing-in period to allow for adjustment by the existing fishermen.

Despite the advantages of using some forms of license fee to discourage an increase of fleet capacity beyond the optimum size, and notwithstanding the increasing number of fisheries in which this is being considered, at present the common practice is precisely the opposite, i.e. the subsidizing of fisheries in such a way that catching capacity is positively encouraged to increase far beyond the optimum level, and indeed also beyond the equilibrium level occurring without subsidy. Given the large fluctuations that occur in most fisheries, pressure for subsidies during poor years is inevitable and any support in poor years is unlikely to be balanced by reductions in support in good years. In international fisheries the situation is worsened by the variety of forms that subsidies can take (direct financial support, grants for new construction, favorable tax structure, etc.). Just as all fishermen blame foreigners for overfishing, so also do they tend to consider the measures of support given by their own government as wholly necessary in the face of unfairly subsidized foreign competition. It has been argued that the problems of too heavy fishing in the Northeast Atlantic would be eased considerably by a general, balanced reduction in the various national forms of subsidy.

POTENTIAL VALUE OF LICENSING SCHEMES

Licensing schemes which involve the payment of high fees bring clearly into focus the main economic decision that has to be taken in relation to any management scheme: who is to obtain the benefit? In an unmanaged fishery the large potential positive difference between the value of the catch and the necessary costs of harvesting are wasted by the progressive accrual of excess costs. In a well managed fishery benefits are available to be distributed, either to the country as a whole, or to a particular sector. For example, if licenses are transferable and the annual fee payable to the government is not large, the benefit will accrue to the existing fishermen in terms of a significant capital value of possession of a license — in western Australia the market value of a lobster vessel with a license is around twice that of a corresponding vessel without license. If the annual license fee is large, the benefits (at least initially) go to the licensing authority and may be used as part of its general revenue or, especially during the transitional period, in helping to finance the resettlement of fishermen displaced under the management scheme.

The limitation of the amount of fishing by a substantial tax or license fee also promises to deal with the most intractable long-term problem, which is that of maintaining the incentive to improve the technical and economic efficiency of the fishery while controlling the amount of fishing (fishing mortality), That father-figure of world fisheries, the late Wib Chapman, strongly opposed the management of fisheries on economic grounds, believing that those engaged in a managed fishery would become soft and inefficient, while the competitive pressures in an unmanaged fishery would encourage the development of improved technology and the maintenance of high efficiency in the existing fishery, as well as the development of new fisheries. There is undoubted force in these views, particularly if the management measures, such as limitation of entry, are chiefly used to protect the interests of existing participants. Undoubtedly, management measures, as well as avoiding the direct imposition of inefficiency (e.g. prohibiting certain types of gear), must also encourage the development of greater efficiency. Clearly, some types of measure such as the issue of licenses to the highest bidder should do this also. Equally, so far as the development of new fisheries is concerned, the prospect of an assured long-term future of reasonable profits under a suitable management scheme should be as effective in attracting new technology, and management and entrepreneurial skills, as the high but transient profits typical of the early stages of unmanaged fisheries.

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Determinants of Demand for Fish and Their Effects Upon Resources[1]

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World population is expected to grow from its present level of 3.7 billion to 4.6 billion in 1980 and 6.6 billion by the end of the century. In order merely to maintain per capita fish consumption at present levels this will necessitate an increased fish supply of some 8 million tons by 1980 and 27 million tons by the end of the century. This excludes allowances for any increase in fish meal consumption.

If under the influence of rising incomes per capita consumption levels also grow, then this will increase further the additional supplies required. On the basis of past trends, per capita demand on a world average might be expected to rise from its present level of 11.8 kg, to 13.3 kg in 1980, and more speculatively to 16.2 kg by the end of the century. On this assumption, the combined effect of population and income growth would be to add by 1980 some 18.5 million tons, and by the end of the century 63 million tons to the present world demand for fish. This again excludes any allowance for increased demand for fish meal for which, it is believed, due mainly to supply limitations, there will be no significant increase in consumption above present levels.

The increases in demand for fish for direct human consumption will, nevertheless, push the exploitation of conventional fish resources to the limit of their potential yields. By 1980, it seems likely that the potential still remaining to be harvested from conventional fish stocks will have fallen from its present level of about 45% to some 30%, and by the end of the century the unexploited potential is likely to be negligible. This rate of utilization assumes, however, that there will be significant increases in production from cultured sources, which could be stimulated by the rising prices likely to be associated with the full exploitation of wild stocks. As more and more wild stocks reach this point, management will become increasingly necessary to prevent the build-up of useless excess capacity of the world's fishing fleets, and in some cases to prevent fishing effort reaching the point at which the productive capacity of the resources becomes threatened.

On prévoit que la population mondiale passera de son niveau actuel de 3,7 milliards à 4,6 milliards en 1980 et à 6,6 milliards à la fin du siècle. Rien que pour maintenir au même niveau qu'aujourd'hui la consommation de poisson par habitant, il faudra augmenter les approvisionnements en poissons: quelque 8 millions de tonnes en 1980 et 27 millions de tonnes en l'an 2000, et cela indépendamment de tout accroissement de la consommation de farine de poisson.

Si, parallèlement au relèvement des revenus, la consommation par habitant augmente aussi, les approvisionnements supplémentaires requis devront encore s'accroître. Sur la base des tendances passées, on pourrait s'attendre à ce que la demande par habitant (moyenne mondiale) passe de 11,8 kg, niveau actuel, à 13,3 kg en 1980 et atteigne peut-être 16,2 kg à la fin du siècle. Selon cette hypothèse, l'effet conjugué de l'accroissement démographique et du relèvement des revenus résultera en une augmentation d'environ 18,5 millions de tonnes en 1980 et de 63 millions de tonnes à la fin du siècle par rapport à la demande mondiale actuelle de poisson. Ici encore, ces chiffres ne tiennent pas compte de l'accroissement de la demande de farine de poisson dont la consommation, estime-t-on, n'évoluera guère en raison surtout de la limitation de l'offre.

Quoi qu'il en soit, l'augmentation de la demande de poisson destiné à la consommation humaine directe incitera à exploiter, à la limite de leurs rendements potentiels, les ressources ichtyologiques classiques. Il est vraisemblable que le potentiel des stocks de poissons classiques qui demeurera encore exploitable sera tombé de 45% (valeur actuelle) à environ 30% en 1980 et aura une importance négligeable à la fin du siècle. Ce taux d'exploitation sous-entend cependant une augmentation notable de la production piscicole, laquelle pourrait être stimulée par la hausse des prix susceptible d'intervenir avec la pleine exploitation des stocks sauvages. A mesure que le nombre des stocks sauvages pleinement exploités augmentera, l'aménagement des ressources sera de plus en plus nécessaire pour empêcher que la capacité des flottilles mondiales de pêche ne devienne indûment excessive et, dans certains cas, pour éviter que l'effort de pêche ne parvienne au point où la capacité de production des ressources sera menacée.

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Se espera que los 3.700 billónes de habitantes del mundo actual sean 4.600 en 1980 y 6.600 billónes a fin de siglo. Para mantener constante el consumo de pescado por persona, será necesario aumentar los suministros en unos 8 millones de toneladas para 1980 y 27 millones para finales del siglo. No queda margen para que aumente el consumo de harina de pescado.

Si por efecto del aumento de los ingresos también aumenta el consumo, tendrán que ser mayores los suministros que se necesiten. Teniendo en cuenta las pasadas tendencias, es de esperar que la demanda media mundial por persona pase de los 11,8 kg actuales a 13,3 kg en 1980 y, aunque esto es más hipotético, a 16,2 a finales del siglo. Basándonos en este supuesto, el efecto combinado del aumento de la población y de los ingresos, sería añadir a la actual demanda mundial de pescado unos 18,5 millones de toneladas para 1980 y 63 millones de toneladas para finales del siglo. De nuevo, esto no deja margen para el aumento de la demanda de harina de pescado ya que, según se opina, y debido principalmente a las limitaciones de los suministros, el consumo no será muy superior al actual.

Los aumentos de la demanda de pescado para el consumo directoharán que la explotación de los recursos pesqueros tradicionales llegue al límite de su rendimiento potencial. Es probable que para 1980 el potencial explotable de las poblaciones tradicionales disminuya del 45% actual (aproximadamente) a 30% y para fin del siglo tal potencial sea insignificante. Esta utilización supone que no habrá aumentos importantes de la producción de la piscicultura, la que podría ser estimulada por el aumento de precios relacionados con la explotación total de poblaciones silvestres. A medida que éstas se aproximen a esa explotación, será necesaria una administración que impida el aumento excesivo e inútil de las flotas pesqueras mundiales y en algunos casos evite que las actividades de pesca alcancen el punto en que la capacidad productiva de los recursos quede amenazada.

Present Pattern of World Fish Consumption

THE activity of fishing is, in the last analysis, an attempt to satisfy a basic human need — the elemental demand for food. While fishery activities are extremely diverse, ranging from localized subsistence fisheries to highly mobile, capital intensive operations, their degree, direction, and species orientation ultimately reflect the demand for fish and fishery products. Thus, although supply and demand are interacting, the complex factors which together determine the demand for fish have perhaps paramount influence upon the extent to which resources of fish are exploited.

World consumption of fish in 1970 was of the order of 65 million tons. It has grown since the early post-World War II period (1949–51) at a rate of some 5.5% annually, which compares with a rate of increase in world population of about 2.0%. Over the two decades since 1950, per capita consumption has increased from about 7.2 to 11.8 kg, but a large part of the increase in world production during this period has been used for reduction to meal and oil which in 1970 utilized some 35% of the total catch. In addition, roughly a million tons, or about 1.5%, is used for pet food, mink feed, or other miscellaneous purposes.

The greater part of the fish meal consumption takes place in the developed countries, which boosts the proportion of the total world fish catch utilized by these countries to about 50%, even though they include no more than about 20% of the world population. By contrast, the developing countries, which contain some 50% of the population, at present consume only about a quarter of the world's fish supplies, most of it directly as human food. The centrally planned economies, which include such populous countries as China and such important fishing nations as the USSR and Poland, comprise about a third of the world population and consume some 25% of the total fish supplies.

Although there are numerous exceptions, the absolute level of per capita fish consumption tends to be associated positively with the level of per capita income. Thus, the developed countries — classified as such by virtue of their high income levels — have an average consumption per head of some 23.8 kg, which is more than three times that in the developing countries. The relative importance of fish in the diet, on the other hand, tends to be associated more with taste, availability, and other factors. Thus, in the developing countries fish accounts for nearly 20% of the animal protein intake, and for nearly one-third in the fish-conscious countries of Asia. In contrast, the relative unimportance of fish in the diet of the developed countries, in spite of their high per capita consumption, serves only to emphasize their already high animal protein intake.

Future Population Increase and Its Effect on Demand

Two of the major determinants of the demand for fish, as for any other commodity, are population and per capita income. Other factors, discussed in more detail below, also have an effect on demand, but to a large extent increases in consumption are dependent on the growth in the number of consumers and increases in their disposable income. Moreover, since we are considering a basic foodstuff, the demand for which over a wide range of countries is rather inelastic with respect to income, population tends to be the main determinant of movement in total demand. It is, therefore, appropriate to look first at the expected future growth in the world population and its probable effects on fish consumption.

The world's population, at present 3.7 billion, will have grown to something in the range 6.1–8.0 billion by the end of this century. Detailed estimates of the world population growth are given in the Appendix but the main points can be briefly summarized here. The lower figure of the above range — the UN low variant — assumes that the rate of population increase in the developed countries will remain unchanged and that in the developing countries it will show a gradual decline to the end of the cen-

TABLE 1. World fish consumption,[a] nutritional standards and the role of fish, 1970.[b]

	Daily Intake of Calories	Fish consumption		Population '000	P.C. Consumption kg/year	Fish as % of animal proteins
		Total	Food			
		'000 tons live wt.				
World	2367	65,266	43,933	3,718,979	11.8	14.0
Developed countries	2962	32,736	17,064	726,976	23.5	11.2
North America	3166	6,081	3,492	226,612	15.4	4.8
Western Europe	2991	17,251	7,235	355,645	20.3	10.2
Oceania	3199	328	191	15,344	12.4	5.0
Others	2491	9,076	6,147	129,375	47.5	47.5
Developing countries	2106	15,787	12,950	1,760,143	7.4	19.3
Africa	2161	2,103	2,015	282,221	7.1	22.8
Latin America	2447	3,097	1,842	283,467	6.5	8.1
Near East	2284	521	409	167,486	2.4	7.0
Asia	1977	10,036	8,654	1,022,882	8.5	31.6
Centrally planned countries	2358	16,743	13,919	1,231,860	11.3	14.9
Asian centrally planned	2035	7,190	7,190	883,548	8.1	27.0
USSR	3165	6,740	5,808	242,554	23.9	8.4
Eastern Europe	3058	2,813	922	105,758	8.7	6.4

[a] Excluding stocks of fish meal and fish used for pet food and other miscellaneous purposes.

[b] Source: M. A. Robinson and A. Crispoldi "The demand for fish to 1980," FAO Fish. Circ. No. FIEF/C131 — FAO, Rome, September 1971.

tury. This is about the most optimistic view of the future that can be taken, and on this basis the demand for fish for human consumption — assuming no increase in per capita consumption — would increase over the 1970 level by some 7 million tons in 1980 and by some 23 million tons at the end of the century.

The upper figure of the range is based on the assumption that there will be no decline in fertility[2] in the developing countries. This is about the worst that might be expected and implies a gradually accelerating rate of population increase which would, for the world as a whole, imply annual additions of some 220 million people. On the basis of this assumption, the growth in the demand for fish for direct human consumption as food would be of the order of 11 million tons by 1980 and — such is the power of geometric progression — some 38 million tons by the end of the century.

There is, however, evidence that fertility is beginning to decline, especially in some of the more populous developing countries of Asia, and the most likely demographic trend is that given by the UN medium variant which assumes that world population will continue to increase by some 2% per annum up to 1985, thereafter the rate of increase declining slightly to about 1.7% by the year 2000. On the basis of this alternative, the increase in the world demand for fish for human consumption — always assuming no rise in per capita consumption — would be 8 million tons by 1980 and 27 million tons by the end of the century.

The developing market economies of Asia are expected to account for a third of the world population increase in the period to the end of the century. On the medium variant (which, it should be remembered, assumes declining fertility) the population of this region is expected to increase from its present level of just over 1 billion, to 1.3 billion in 1980 and 2.1 billion by the year 2000. Fish is a staple food in many parts of this region, even though per capita consumption is only 8.5 kg. Nevertheless, merely to maintain this inadequate level of consumption in these countries will require an additional 2.6 million tons of fish by 1980 and 9 million tons by the end of the century.

In spite of their lower rate of population increase the developed countries, by virtue of their generally higher per capita consumption, will also require fairly substantial quantities of fish to maintain present levels. The "other" developed countries, heavily influenced by Japan, will require roughly an additional 120,000 tons each year over the 30-year period, and North America, where overall fish and shellfish production have shown no increase for many years, will require an additional half a million tons by 1980 and an extra million tons in the course of the following two decades.

Population growth will also tend to increase the demand for fish meal, although there is no very clear historical relation between these two magnitudes. The rapid growth in the demand for fish meal during the late 1950s and early 1960s was largely the effect of the more widely applied knowledge of the nutritional needs of livestock. Market expansion has thus been due mainly to technological change which has completely swamped any effect that population growth may have been exerting. The future trend in the demand for fish meal is also subject to greater uncertainty than that for direct human consumption on a number of grounds discussed more fully below. No esti-

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[2] The number of children born per given number of women.

TABLE 2. Additional supplies of fish[a] required to maintain 1970 per capita consumption in 1980 and 2000, in thousands of tons live weight.

	Actual consumption 1970	Increase Required if Population Growth is					
		1980			2000		
		Low	Medium	Constant Fertility	Low	Medium	Constant Fertility
World	43,933	7,316	8,228	9,412	23,069	27,252	38,210
Developed countries	17,064	1,938	1,952	1,952	5,916	6,073	6,208
North America	3,492	416	416	416	1,507	1,507	1,507
Western Europe	7,235	551	551	551	1,692	1,692	1,692
Oceania	191	41	41	41	133	133	133
Others	6,147	930	943	943	2,583	2,740	2,875
Developing countries	12,950	3,554	4,015	4,354	12,004	14,670	20,714
Africa	2,015	570	623	621	2,199	2,711	2,958
Latin America	1,842	560	604	666	2,071	2,386	3,027
Near East	409	113	125	133	438	516	701
Asia	8,654	2,302	2,654	2,923	7,264	9,022	13,983
Centrally planned countries	13,919	1,824	2,261	3,106	5,149	6,509	11,288
Asian centrally planned	7,190	1,116	1,553	2,398	2,908	4,268	9,047
USSR	5,808	627	627	627	2,027	2,027	2,027
Eastern Europe	922	80	80	80	213	213	213

[a] For direct human consumption excluding fish meal.

TABLE 3. Estimated demand for fish in 1980 and 2000 due to income and population increase.

	P.C. consumption kg/year			Est. population millions		Total demand '000 tons live weight		
	Actual	Projected		Medium variant		1980		2000[a]
	1970	1980	2000	1980	2000	Human consumption	Fish meal	Human consumption
World	11.8	13.3	16.2	4,575.2	6,640.3	60,969	33,295	107,548
Developed countries	23.5	26.5	28.7	805.3	977.6	21,372	25,140	28,075
North America	15.4	16.7	17.7	253.8	324.6	4,230	4,180	5,745
Western Europe	20.3	24.0	26.6	383.5	439.8	9,208	15,710	11,699
Oceania	12.4	13.6	15.2	18.7	26.1	254	375	397
Others	47.5	51.4	54.7	149.3	187.1	7,680	4,875	10,234
Developing countries	7.4	8.7	11.7	2,306.0	3,789.9	20,131	3,165	44,405
Africa	7.1	8.7	9.3	371.5	665.7	3,249	260	6,191
Latin America	6.5	7.6	9.2	376.2	650.5	2,854	1,965	5,985
Near East	2.4	3.0	3.5	222.6	385.3	658	110	1,349
Asia	8.5	10.0	14.8	1,330.3	2,079.5	13,324	810	30,777
Centrally planned countries	11.3	13.3	18.7	1,463.9	1,872.8	19,466	4,990	35,068
Asian centrally planned	8.1	9.5	14.8	1,079.4	1,414.6	10,253	—	20,936
USSR	23.9	29.7	37.9	269.3	327.8	7,996	2,600	12,424
Eastern Europe	8.7	10.6	13.1	115.2	130.4	1,217	2,390	1,708

[a] Estimates of fish meal demand in 2000 are not reliable enough to be useful.

mate of the future demand for fish meal arising from population increase has therefore been included in Table 2.

Income Growth and Its Effect on Fish Consumption

Even though population will continue to increase into the foreseeable future, it would be unrealistic not to expect some improvement in per capita income levels during the remaining decades of the century. This, too, will increase the demand for fish. Projections of income growth up to 1980 are available from a number of sources and the rates used in the calculation of data for Table 3 are those on which the recent FAO Agricultural Commodity Projections[3] were based. These are essentially modified extrapolations of past trends which assume that total world private consumption expenditure at constant 1970 prices will increase at a compound rate of about 5.1% per year up to 1980. Marginally higher than the average annual increments in the past decade, the projected increases reflect the accelerating pace of economic development in the world as a whole. Nevertheless, although there are marked national variations the three broad economic groupings show remarkably similar trends — the rate for both the developed and developing countries being the same as the world average.

Beyond 1980 projection of economic trends becomes largely speculation. Nevertheless, it would be surprising if income levels did not continue to rise after 1980, although historically evidence suggests that as the absolute level rises the rate of increase may show some decline. Thus, for the last two decades of the century somewhat different rates of income increase have been selected for the three broad regions, based on relative levels of income. This has the effect of reducing the projected annual rate of growth of world private consumption expenditure in the period 1980–2000 to around 4.5%.

The effect of changes in income on the demand for fish (or any other commodity) varies according to tastes, the level of consumption already being enjoyed and a variety of other factors. For many countries data on which estimates of this relation may be based are sparse or even lacking entirely. Such evidence as is available, however, suggests that variation in income produces less than proportionate changes in the demand for fish, although generally speaking the relation is more sensitive in developing countries where, because of lower levels of consumption, a rather larger proportion of any increase in income is spent on food than in developed countries whose per capita intake of many foods has reached saturation point. Typical income elasticities are represented by 1.0 for Indonesia implying that a 10% increase in income would generate a 10% increase in the quantity of fish purchased, and the United States where a 10% increase in income would tend to produce only a 2.8% increase in the demand for fish.

The projected effect of income on per capita demand is shown in Table 3. On the basis of what is essentially a continuation of past trends, the average per capita consumption of fish in the world would rise by 1.5 kg in the present decade and by a further 3.1 kg in the succeeding two. In spite of generally low income elasticities, the impact of income on per capita demand is most marked in the developed and centrally planned countries of Eastern Europe, where the effects of increases in total GNP on per capita income are less diluted by population growth than they are in the developing countries. Thus, in the advanced industrial countries of Europe and North America the increased per capita consumption generated by income growth to 1980 has the effect of more than doubling the increase in total demand over that which would be produced simply by population expansion acting on an unchanged level of consumption; in the developing countries the corresponding increase is no more than 60%.

In the final two decades of the century, in spite of further increases in income, the rate of increase of per capita fish consumption in the developed world is expected to slow considerably as consumption in some countries nears or reaches saturation level. For the great majority of developing and centrally planned countries, with the exception of the USSR and some Eastern European countries, saturation seems an unlikely eventuality, although some change in attitude to fish consumption in these countries is postulated from about 1985. Up to this point it is assumed that increases in fish consumption have no effect on attitudes towards further increments in consumption; from 1985 onward, however, it is assumed that the coefficient of income elasticity of the demand for fish will decline as consumption increases. This is something of a generalization and clearly there are some countries with low nutritional levels where this will not happen; nevertheless, income growth will still continue to generate increased demand for fish. In Japan, for example, even though the rate of income growth is expected to fall from the higher levels presently being recorded it will still be considerable, and even though the effect on fish consumption will weaken it will still raise per capita demand by rather more than 3 kg over the two decades. In the developing countries over the same period consumption is projected to rise by a further 2 kg and in the centrally planned countries by 5.4 kg.

In spite of increasing pressure on world fish resources for food for direct human consumption, it seems probable that by 1980 substantial quantities of fish will continue to be converted into fish meal and oil. Although on the basis of 1970 relative price levels it seems unlikely that fish meal will increase its share of the animal feed market, demand will continue to increase as broiler and pig production in developed countries increases and as other countries continue to adopt more scientific methods of animal production. The estimated demand for fish meal in 1980 given in Table 3 has been calculated on this basis — it being assumed that fish meal consumption will increase at the same rate as oilcake feeds in general.

The constant relative price assumption on which the projections have been made is, however, rather unrealistic in the case of fish meal. Although this assumption is nearly impossible to relax in a systematic manner, taking into account future price variations in competing natural and synthetic sources of protein, it is at least clear that supply constraints will limit any significant increase in consumption. While limited local possibilities for increased production of meal exist, in general any substantial increase in the supply of fish meal can only be produced by turning to less abundant stocks than those now exploited, with consequently higher costs of exploitation. Any marked increase in the price of fish meal would, however, severely restrict its usage and would therefore decrease its share of the market. In view of the uncertainty surrounding the long-term future of fish meal, no estimate has been made for 2000 and that for 1980 should be viewed in the light of the above qualifications.

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[3] Agricultural Commodity Projections, 1970–80, Vol. I and II, FAO, Rome, 1971.

It is, nevertheless, clear from Table 3 that improvements in the standard of living taken out in the form of greater fish consumption are likely to have a significantly increased impact on the world's fish resources. The combined effect of a cumulative growth of 2% per annum in the population and of 5% in Private Consumption Expenditure would by 1980 generate an additional 18.5 million tons to the total world demand for fish for human consumption. By the year 2000 the increased demand would be over 63.0 million tons greater than in 1970. Both of these figures exclude any increase in the demand for fish meal, although by the later date it is probable that some at least of the fish now going into fish meal production will have been upgraded for use as human food.

Price and Other Influences on Demand

As already mentioned, the estimates shown in Table 3 have been made on the basis of constant relative prices, although price is recognized to be an important factor influencing demand. As already indicated, relaxing the assumption of constant prices involves the incorporation in the demand model of allowance for the supply and demand response to price changes of all competing commodities. The main cause of increases in the price of fish is in fact increased demand operating on increasingly inelastic supply. Although as exploitation proceeds and fish abundance declines the cost per ton of fish produced will tend to increase, there is very little empirical evidence to support the view that increases in the cost of capture have any significant direct effect on the price of fish. The main effect of such cost increases in the past has usually

TABLE 4. Catch of marine fish, crustaceans, and cephalopods (1970), and estimated world potential by marine area and species, in thousands of tons.

	Oceanic pelagic		Demersal		Shoaling pelagic		Cephalopods		Crustaceans		Total	
	1970 catch	Potential	1970 catch	Potential	1970 catch	Potential	1970 catch	Potential	1970 catch	Potential	1970 catch	Potential[a]
Atlantic Ocean												
Northeast	54	1,100	5,575	6,600	4,309	6,700	41	1,000	141	170	10,120	45,700
Northwest	13		2,283	3,600	1,228	2,800	16	500	99	100	3,639	
Western Central	40		224	2,000	741	3,000	3	1,000	214	260	1,222	
Eastern Central	220		668	930	1,546	1,900	106	700	40	80	2,580	
South Western	33		706	3,800	193	3,500	1	1,000	64	110	997	
South Eastern	47		898	1,080	1,434	3,200	2	500	29	50	2,410	
Total Atlantic	407	1,100	10,354	18,010	9,451	21,100	169	4,700	587	770	20,968	45,700
Pacific Ocean												
Northeast	266	2,200	690	3,800	128	2,500	0	1,000	103	100[b]	1,187	55,500
Northwest	632		9,065	10,000[c]	3,406	3,200	627	1,000	246	300	13,976	
Western Central	28		2,455	6,500	745	4,000	25	200	263	680	3,516	
Eastern Central	309		188	1,400	220	3,700	9	300	73	110	799	
Southwest	74		76	200	14	400	0	500	13	40	177	
Southeast	97		170	600	13,288	12,000	1	500	42	80	13,598	
Total Pacific	1,406	2,200	12,644	22,500	17,801	25,800	662	3,500	740	1,310	33,253	55,500
Indian Ocean												
Eastern	56	700	813	3,000	170	2,000	0	500	46	110	1,085	14,850
Western	156		681	4,400	630	4,000	3		169	140	1,639	
Total Indian	212	700	1,494	7,400	800	6,000	3	500	215	250	2,724	14,850
Mediterranean Sea	43	45	267	400	531	800	43	500	26	50	910	1,800
World total	2,068	4,045	24,759	48,310	28,583	53,700	877	9,200	1,568	2,380	57,855	117,850
Indicated expansion factor	×1.96		×1.95		×1.88		×10.49		×1.52		×2.04	

[a] Figures for potential may not add horizontally due to rounding.
[b] Potential of Pandalid shrimps probably underestimated.
[c] Revised estimate.

been to reduce profits and thereby induce cost saving innovations. Nevertheless, to the extent that fish stocks become fully exploited to the point at which further increases in fishing effort yield no sustained increase in catch, greater demand can only be reflected in higher prices. It is, however, important to bear in mind that such increases are the effect of limited supply and not the cause; it does not therefore seem likely that higher prices will restrict the full development of resources, although they will, in the long run, affect the distribution of fish consumption among income groups.

Other influences on the demand for fish, equally difficult to quantify, include such factors as availability and changes in consumer preferences. The influence of the first of these factors on demand over the next three decades is, in many countries, likely to be strongly positive. Deficiencies in the distributive sector are probably the major constraint to greater fish consumption in many parts of the world, particularly in the less developed countries, not only because of their effect on price but also simply because they prevent the wider and more regular availability of fish and fishery products. With the development of better communications and the general economic infrastructure in developing countries, fish will almost certainly become more widely and readily available and therefore more regularly consumed. In the developed countries the continued extension of freezing as a cheap means of preserving fish in good condition, as well as new product development, will also tend to increase consumption through wider availability.

While one of the assumptions on which the projections to 2000 have been made is that by the end of this period attitudes in many countries will, as a result of increase in consumption, be less favorable to further increase in consumption, some forces are nevertheless likely to operate in favor of greater consumption. This will probably be the case in primarily meat eating countries where, as saturation point in meat consumption is reached, consumers may turn to fish as a means of providing greater variety in the diet. At the other end of the scale, in low income countries economic development is breaking down tribal customs and taboos, some of which operated against the consumption of fish, and it is already evident that the greater availability of fish in these areas is having a marked effect on preferences. In spite of periodic scares — such as the recent fear of mercury in tuna — it seems probable that future shifts in food preference patterns will favor greater consumption of fish.

Future Supply Possibilities

The most recent estimates summarized in Table 4 indicate that the world's resources of marine fish, crustaceans, and cephalopods are potentially capable of sustaining an annual catch of about 118 million tons, on the optimistic assumption that fishing effort on each stock is adjusted to take the maximum sustained catch. The potential output of molluscs other than cephalopods and of inland water species (excluded from the above total), which depend largely on cultivation, is technically very large, but is constrained by economic forces. Output from these sources depends largely on the cost of production compared with market opportunities, and thus indirectly depends on the intensity of exploitation of the natural marine stocks.

Comparison of future demand with potential is made in Table 5. To the potential for marine species has been added an estimate for the probable production from freshwater sources and from culture of all kinds. Present production from these two sources amounts to some 10 million tons and can reasonably be expected to grow to some 17 million tons in 1980 and, more speculatively, to 32 million tons by the end of the century. These estimates are based on probable income and population growth over the period and imply a gradual increase in per capita consumption of such products from around 3 kg at present to 3.5 kg in 1980 and to nearly 5 kg by 2000.

TABLE 5. World fish resources potential supply and estimated demand, in millions of tons live weight.

	1964/66	1970	1980	2000
Consumption				
Meal	18.1	26.5	33.3	?
Food	34.2	43.9	61.0	107.5
Total	52.3	69.4	94.3	?
Supply				
Potential marine fish, crustaceans and cephalopods	118.0	118.0	118.0	118.0
Estimated production freshwater fish and cultivated species	6.0	10.0	17.0	32.0
Total	124.0	128.0	135.0	150.0
		Percentage		
Unharvested potential	57.8	45.7	30.3	Negligible

It is clear from the comparison presented in Table 5 that world fisheries are approaching a critical period. In 1965, over half the world's known conventional fish resources remained unexploited, but if demand expands under the impact of increasing population and rising living standards as projected then rather less than a third of the potential will remain unharvested by 1980. The uncertainty surrounding the future of fish meal makes it impossible to say how much further this process will have gone by the end of the century, although the intensity of exploitation will certainly be much greater than in 1980 — even given the possibility that some stocks now exploited for fish meal will by then be used for direct human consumption. All the evidence suggests that it can be assumed for all practical purposes that no stocks of conventional fish will have any significant potential remaining by the end of the century.

The traditional answer to the problem of the full exploitation of one species has been the diversion of demand to less heavily fished stocks. Product development is, it is true, making species a less relevant consideration and world catch statistics today include a number of species that were of little commercial interest a few years ago. For example, landings of round-nosed Grenadier (*Macrourus rupestris*), not identified in North Atlantic catch statistics until 1967 were some 80,000 tons in 1971. Similarly, landings of Cape anchovy (*Engraulis capensis*), nil in 1963, were of the order of 400,000 tons in 1970.

Nevertheless, to the extent that demand is species-directed the situation is rather more serious than suggested by a straight comparison of future demand with the remaining unharvested potential. As will be seen from Table 4 many of the underexploited species which are found in relative abundance, for example the cephalopods and small pelagic species, face marketing problems and cannot be considered adequate substitutes for many of the heavily exploited fish, such as prime groundfish, salmon, and lobster. Furthermore, much of the unexploited potential lies in tropical areas. Although these stocks are numerous, they are generally small and dispersed and are much less attractive commercially than single species stocks of more temperate latitudes.

Finally, it should be mentioned that some of the marine areas shown in Table 4 — for example the southeastern Pacific and the northwestern Pacific — are already very heavily exploited and have only a minimal contribution to make to further increases in the world fish supply. The major areas of remaining unexploited potential do not, however, always coincide with the major markets and further intensification of fishing in these areas can be expected to exacerbate the international differences which are already disturbing relations between coastal states and nations with long-range fishing fleets.

Conclusion

The need for the effective management of world fishery resources, already great, is likely to grow more urgent as the pressure of demand increases. This is true not only of the already heavily exploited stocks but also of those now relatively lightly exploited on which the intensity of fishing effort is beginning to grow. To take a larger share of those common property resources which still exist, the pace of technological change is accelerating, but even with present techniques a fishery can move from a practically virgin state to one of overexploitation in the course of a few seasons. Catches of capelin have, for example, increased from half a million tons to one and a half million tons in the space of three seasons. Catches of Alaska Pollock have shown similar dramatic increases from just over a million tons in 1966 to over 3 million tons in 1970.

In the long run, unless culture operations are developed on a much expanded scale, there is nothing to prevent a fall in the per capita consumption of fish on a world basis, although consumption of some groups may be increased in some areas at the expense of others. As population and income and therefore demand increase while the resources remain fixed, prices will tend to increase and more and more fish species will become luxury items. In these circumstances, management will become increasingly necessary to prevent the build-up of wasteful fishing capacity and to control the excessive inputs which would otherwise continue to be drawn into fishing operations. More fundamentally, perhaps, management is necessary to ensure that fishing effort is not pushed to lengths which not only reduce the total catch but even threaten the productive capacity of the resources.

APPENDIX 1. World population (1970) and alternative growth variants to 1980 and 2000, in millions.[a]

	1970	1980			2000			Increase (medium assumption)	
		Low	Medium	Constant fertility	Low	Medium	Constant fertility	1980 vs. 1970	2000 vs. 1970
World	3719.0	4460.3	4575.2	4723.8	6108.8	6640.3	8028.8	856.2	2921.3
Developed countries	727.0	805.0	805.3	805.3	974.3	977.6	980.4	78.3	250.6
North America	226.6	253.8	253.8	253.8	324.6	324.6	324.6	27.2	98.0
Western Europe	355.6	383.5	383.5	383.5	439.8	439.8	439.8	27.9	84.2
Oceania	15.3	18.7	18.7	18.7	26.1	26.1	26.1	3.4	10.8
Others	129.4	149.0	149.3	149.3	183.8	187.1	189.9	19.9	57.7
Developing countries	1760.1	2245.4	2306.0	2350.3	3429.6	3789.9	4585.6	545.9	2029.8
Africa	282.2	364.1	371.5	371.3	593.6	665.7	700.5	89.3	383.5
Latin America	283.5	369.6	376.2	385.9	602.0	650.5	749.0	92.7	367.0
Near East	167.5	217.5	222.6	225.6	352.8	385.3	462.6	55.1	217.8
Asia	1022.9	1288.9	1330.3	1362.0	1872.7	2079.5	2663.2	307.4	1056.6
Centrally planned countries	1231.9	1409.9	1463.9	1568.2	1704.9	1872.8	2462.8	232.0	640.9
Asian centrally planned	883.5	1025.4	1079.4	1183.7	1246.7	1414.6	2004.6	195.9	531.1
USSR	242.6	269.3	269.3	269.3	327.8	327.8	327.8	26.7	85.2
Eastern Europe	105.8	115.2	115.2	115.2	130.4	130.4	130.4	9.4	24.6

[a]Source: UN Population Division, Department of Economic and Social Affairs: "World population prospects, 1965–2000, as assessed in 1968," ESA/WP. 37, December 1970.

Financing Resources for Fishery Development[1]

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LUNA-MUÑOZ, J. 1973. Financing resources for fishery development. J. Fish. Res. Board Can. 30: 2059–2064.

The provision of finance for fishery development is often one of the most difficult problems for the developing countries to solve for a variety of reasons, such as lack or insufficiency of data about the resource concerned, inadequacy of the infrastructure and other supporting services, low level of technical management and skills, lack of marketing and distribution, and so on. Yet there are many sources for investment funds and, indeed, an increasing availability of such funds from the national public and private sectors, and from international sources. These include governmental and private sources and cover a number of investment arrangements from direct cash participation to credit systems and joint ventures. Also included are the international finance agencies, such as the World Bank Group and the complementary regional banks. These are playing a bigger role now than ever before in fishery development. The general criteria for an investment in fisheries, steps that have to be taken before a decision can be reached to undertake an investment, financial sources and arrangements available to the developing countries, and how they can best go about obtaining the required investment funds, are reviewed.

Le financement du développement des pêches représente bien souvent l'un des problèmes les plus ardus que doivent résoudre les pays en voie d'expansion, et cela pour diverses raisons dont l'absence ou l'insuffisance des données sur les ressources en cause, l'inadéquation de l'infrastructure et des autres services de soutien, le faible niveau des compétences techniques, le manque de réseaux de commercialisation et de distribution, etc. Il existe pourtant de nombreuses sources de fonds, et les possibilités d'obtenir des crédits à l'échelon national (secteur tant public que privé) et international se multiplient même. Il s'agit dans ce cas de sources gouvernementales et privées, qui prévoient un certain nombre de modalités en matière d'investissements allant de la participation financière directe à des systèmes de crédit et à des entreprises conjointes. Il faut également citer les institutions financières internationales telles que le Groupe de la Banque mondiale et les banques régionales. Ces institutions jouent un rôle plus important que jamais dans le développement de la pêche. Les critères généraux applicables aux investissements dans le domaine des pêches, les mesures préliminaires à prendre avant qu'intervienne une décision en matière d'investissement, les sources et formules de financement accessibles aux pays en voie de développement et la manière dont ces derniers peuvent obtenir les fonds qui leur sont nécessaires, sont examinées.

Obtener recursos financieros para la explotación de la pesca contituye frecuentemente uno de los problemas más difíciles que tienen que resolver los países en desarrollo por una diversidad de motivos, tales como la falta o insuficiencia de datos acerca de los recursos, inadecuación de la infraestructura y otros servicios auxiliares, mala gestión técnica y carencia de mercadeo, distribución, etc. Sin embargo existen muchas fuentes y mayores disponibilidades de fondos de inversión procedentes de los sectores nacionales, públicos y privados y de los internacionales. Estos últimos incluyen fuentes gubernamentales y privadas y comprenden cierto número de acuerdos de inversión que van desde la participación directa en efectivo, a los sistemas crediticios y empresas conjuntas. También quedan incluidos los organismos de financiación internacional, como es el caso del grupo que integra el Banco Mundial y los bancos regionales. Todos ellos desempeñan un papel cada vez más importante en la explotación de los recursos pesqueros. El autor examina los criterios generales que son necesarios para la inversión en la pesca, las medidas que han de tomarse antes de una decisión, para efectuar la inversion las fuentes de financiación y los acuerdos sobre ella que peuden hacer los países en desarrollo, así como la forma que tienen de obtener los fondos de inversión necesarios.

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February, 13–23, 1973.

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Areas of Financing

PREINVESTMENT ACTIVITIES

These include all preliminary stages before a decision is made for investment, such as:

Basic information — This is required to determine the maximum sustainable yield. It is difficult to arrive at a conclusion in regions that have never been intensively exploited. This difficulty produces the first practical problem because developing countries are not disposed to wait for research to be done before starting to develop. However, the problem can be solved if the initial projection for development is carefully established under a conservative but flexible program.

Finance for these kinds of operations comes mainly from public funds, directly or through subsidies to private research organizations. Consequently, there is great scope for international financial institutions to participate in them.

Feasibility studies — As soon as an initial appraisal concerning the available resources is completed, all the technical–economic models must be tested in order to permit the conversion of a preinvestment project to an investment project. The institutional structure necessary for the proposed project must always be considered in these models. In the institutional area, there is a group of factors relating to legislation, government administration, technical management, and skilled personnel, all of which are required to implement the project. A lack or insufficiency of these can render unfeasible projects that have no economic or technical limitations.

Finance for feasibility studies frequently comes from public funds, but the private sector can also participate, especially when there is evidence that the project could be profitable or when the government offers incentives to do so. Multilateral financial agencies cooperate in this area by financing these special studies, and by helping developing countries to recognize possibilities for development.

Preparation of investment projects — How to prepare a project is not a problem since manuals and guidelines are available and experts are able to cooperate in the technical work that is involved at this stage. While a number of sources of funds are normally available, obviously the private sector should not hesitate to participate in these operations if the feasibility studies offer a positive prospect for profit.

Governments are also able to participate in the financial effort, particularly where public services are involved, such as fishing ports or terminals. The international financial agencies are also able to collaborate in the preparatory stages of investment projects although some differences exist between projects with easy access to private resources and those which need international financial assistance. Management organization is essential for the first category while, for the others, a dynamic public administrative structure is an additional important requirement.

INVESTMENT PROJECTS

Three types of fishery investment projects can be considered for financial purposes:

Specific projects — These refer to a particular field in the fishery sector independent of other areas, such as financing a tuna industry in a certain country, or financing cooperatives for coastal fishermen or the construction of a fishing harbor.

Integrated projects — These involve all or most of the main areas of the fishery sector, such as preinvestment studies, investments in fishing harbors, fishing terminals and fleets, processing, marketing, training, and research. For the financing of integrated projects, consideration must be given to the institutional structure which must be geared so that development covers all stages and areas of the program. Such projects permit efficient action by both technical and financial international agencies as they can offer the countries complete sectoral planning, properly financed. The cooperative programs FAO/IBRD and FAO/IDB are good examples of this. In the cooperative program between FAO and the Inter-American Development Bank, projects for US $110 million have been prepared in less than 2 years at very low cost to the countries concerned. Such an integrated program involving specific projects and subprojects within an adequate institutional framework not only permits ordered development but also extends opportunities for private investors and avoids subsectoral inefficiencies.

Global projects — A loan granted to a country to be redistributed to sub-borrowers through national financial agencies, either private or public, constitutes a "global project." It is essential that one or more general objectives be determined as the final sub-borrowers and their projects are not known in advance. The subloans are granted in accordance with the overall objectives of the project and follow established guidelines for credit operation.

Frequently global projects are oriented to reinforce the development of a whole economic sector. It could be for "development of the small manufacturers and fishing industry," or for "agriculture and fishery cooperatives." In other words, such operations are intended to distribute financial resources to a wide range of small beneficiaries. Sometimes the financing of global projects represents the only effective way for international financial agencies to collaborate in development of sectors or subsectors. In the case of fishery subprojects included in global projects, there are some risks to be considered. Cases can be cited, such as funds for fishing boats which end in failure because service for the fleet lacks basic organization, or because the necessary distribution system to handle the increased production was not taken into account. In some countries there are fishing ports without fleets, or cold storage facilities with no fish available, or factories without sufficient vessels to supply them. There are also cases, of course, where there are excessive numbers of boats or other forms of overcapacity. It seems most suitable to use the "global" approach in fisheries mainly for areas which have some level of development and where the subsector to be assisted is clearly defined, such as, for example, the renewal of a shrimp fleet in a country where this industry is already well established. Similarly, it could involve the improvement of a fleet for fish meal in a region where this activity is already partially developed.

TECHNICAL ASSISTANCE

This field is eligible for financing in the preinvestment as well as the implementation stage of an investment project. Finance for technical assistance can be provided in different ways. Bilateral agreements between countries is one; another is the participation of private institutions, whether nonprofit or commercial. International financing agencies also support technical assistance, with particular emphasis on any area which can lead to a final development project.

The tendency now is to use executive and intensive technical assistance for the identification and promotion of specific investment projects. This philosophy requires reorganization of the international technical and financial agencies, since the former will have to change their methods in order to achieve a fresh approach and speed their assistance, and the latter will have to give financial support to this kind of assistance. Such adaptation is evidenced in the recent reorganization of the UNDP, the reorganization of FAO both at Headquarters and in the field, and in the cooperative agreements between technical and financial agencies.

Mr Roy Jackson, Deputy Director-General of FAO, addressing the FAO Committee on Fisheries in April 1972, pointed out that: ". . . to retain the confidence of governments and industry they (the international bodies) will have to prove their ability to take action promptly and decisively; to develop a capacity for sound judgement based on partial facts and an empirical approach rather than emphasizing the comprehensiveness of scientific proof which requires so much time that there may no longer be a problem because a resource may have been depleted . . ."

Formerly, technical assistance could be financed through international agencies in two main ways: nonreimbursable loans or regular loans. A third form, the so-called "contingent reimbursement loan" can become reimbursable if a loan is granted for the investment project prepared. In this case, the cost of the technical assistance is added to the total loan.

Since the financial agencies only supply the money to cover the cost of the technical assistance, it is the responsibility of the national institution concerned to obtain the specific technical assistance required from private consultants or international technical agencies. The cooperative agreements between the financial agencies and the UN technical bodies facilitate the latter's participation but do not exclude the private sector. There are important areas which are not covered by the technical agencies of the UN and countries which are not members of these agencies. Moreover, international agencies can also subcontract work to private firms.

Some factors exist that could influence the decision regarding technical assistance. For example, sometimes intergovernmental agencies such as FAO, UNIDO, UNESCO, or WHO can offer services more rapidly and at a lower cost than can private concerns because their permanent technical staff is ready to work in any area of the world on a basis of fixed salary. There is also the case where recommendations involve political decisions. It is often easier for governments to accept such recommendations if they come from an international agency rather than from a private firm of consultants.

Since the reasons for the selection of a source of technical assistance varies in each case, it is important to maintain flexibility in the use of funds for such assistance. An important additional factor with investment projects is that technical assistance can lead to very serious monetary obligations, and it is not clear at what stage it is possible for the intergovernmental technical agencies to accept such responsibility.

ORDINARY OPERATIONS

Financing normal operations on the project after the investment has been made refers to the working capital and funds from commercial banks or other sources.

Working capital — A healthy fishing venture has to have the necessary self-supporting working capital. The amount needed must be determined by considering such factors as the fishing seasons, the nature of the final product, and its marketing. For instance, a fish meal factory with a normal supply of raw material almost all year and with access to a stable market, does not require heavy working capital since sales bring in a continual flow of funds to pay for inputs. The situation is similar with industries that supply fresh fish to local markets because the products are sold at the end of each trip, generally for cash. But the situation is very different for those industries which can operate only for a few months during the fishing season, and have to process all their material in a short time for sale over a period of a year. In such cases the industry obviously requires a much heavier working capital.

Short-term banking credits—The decision to apply to commercial banks for short-term credits for working capital depends on the comparison between the cost of the credit and that of using one's own funds. The cost of the bank credits includes the rate of interest, commissions, taxes, and other charges. This analysis, of course, is valid only when the alternatives exist. Where there are no other funds, enterprises have to go to the banks. If the cost of credit is reasonable, a firm will take the loan, and this is normal in countries with a high level of inflation where sometimes the cost of credit is less than the rate of inflation. However, this question should be considered very carefully because it is dangerous for a fishery enterprise to depend too heavily on short-term credits. A sudden scarcity of fish, which can easily occur in fisheries, could bring the company to the verge of collapse.

Credits from suppliers or purchasers — Another way of financing is to use credit from suppliers as well as money paid in advance for products. It is normal in the fishing industry to have considerable inventories of some inputs, such as spare parts for engines, nets, ropes, electronic parts, propellers, etc., all of a high value. The decision to pay in cash or to take these materials on credit will also depend on the cost of the credit. The rate of inflation could make it favourable to accept the credit if the price of the goods is fixed, but with imported goods, the situation could be hazardous since the internal earnings could not be increased to keep pace with the devaluation of the national currency. This is particularly serious for industries which have to sell their entire production in the local market.

Arrangements for payment in advance for goods vary according to the market of the country. The most relevant factor to consider, besides inflation, is the accuracy of any forecast of market behavior. An unpredicted rise or fall of prices could produce trouble.

Special systems of financing — A fishery development policy can offer possibilities for helping the fishing industry to obtain finance for their ordinary operations. Governments are paying increasing attention to this matter since the fishing industry promises to become the cheapest source of animal protein. For example, Brazil and Chile have used a system of financial support for fisheries similar to that existing for agriculture. It includes long-term discounts on promissory notes both for the purchase of inputs and the sale of seasonal products.

In some countries "warrants" or general deposit certificates are used for financing seasonal production of fish meal or canning.

Other sources of financing include the various kinds of subsidies, both direct or indirect. One of the most commonly used in developing countries is the return of taxes included in the cost of goods for export ("draw-back"). Sometimes this is given to compensate the exporters for a low rate of monetary exchange. Direct subsidy for some inputs, for example vessels built in the USA for the American industry, are intended mainly to reduce the necessity for investment funds. The special preferential taxation of goods within regional markets, as in the EEC, COMECON, LAFTA, CARIFTA, CACOM, Andean Pact, etc., represents a certain financial "plus" for benefitting products.

Industries protected by customs barriers against foreign competition gain in the same way because they get the highest price for their products in the internal market.

Sources of Money

For a proper picture of the various sources of money for fishery development, a distinction must be made between local resources from the private sector, national resources from the public sector, and foreign resources both from private or public sources, either bilateral or multilateral.

LOCAL RESOURCES FROM THE PRIVATE SECTOR

There are interesting examples to illustrate how to attract private investors to the fishery sector in developing countries. In the Latin American area there is the impressive case of the fishery development of Peru which has come largely from the spontaneous action of the private sector, at a time when the Government had neither the experience nor the means to develop the fishery. A considerable amount of capital came from foreign firms, especially American corporations, where the market for fish meal was most attractive. The equally impressive development of the Chilean fishing industry, on the other hand, was government-initiated and supported by the strong governmental structure. The action of the Government was followed by private capital. However, in both countries serious problems affected early development because of subsectoral inefficiency, miscalculation in investment dimension, and lack of concerted action in the international markets. At present both countries, which together take 20% of the total world marine catch, control their industry through central planning.

Another interesting experience is that of Brazil, which promoted a considerable amount of private investment in the fishery sector through a system of incentives based on tax deductions. Private industry took the responsibility for their own decisions and according to FAO reports of that time, this policy permitted development under a clear free-enterprise system.

Two basic elements must be considered in the process of acquiring funds from private capital. The first is to have a national master plan to orient and guide the decisions of the investors. The other is to devise a system of incentives sufficient to compensate private capital for the risks involved in the new venture, and to assure the stability of the system to permit the normal economic operation of the investment.

NATIONAL RESOURCES FROM THE PUBLIC SECTOR

Besides direct investment, the financial participation of the public sector can also be effective through credits for investment and tax exemptions or deductions. A policy of tax incentives could mean deductions from income tax for funds destined for fishery investment, and deductions to offset customs tariffs for imported capital goods. In order to reinforce the initial operation of a project, it is usual for the government to lower export taxes for fishery products and to exempt some inputs from sales taxes. Subsidies are another way to support fishery projects, although these are not the ideal way to strengthen a new activity.

Spain and West Germany renewed practically all their fishing fleet during the post-second World War period through a convenient credit policy. Resources for a credit policy can be acquired from internal public revenues or from international credits to the government.

FOREIGN FINANCIAL RESOURCES

The main sources of foreign funds for fishery development are: private investors; loans from suppliers of equipment; bilateral financing agreements, and loans from multilateral financial agencies. The latter are used preferably when no other funds are available, or when the rates charged by other available sources are incompatible with the internal rate of return for the project.

Private investment — There is a tendency in developing countries to limit direct foreign investment to minor participation. The reasons are various, some political, others concerned with problems of balance of trade and fear of "debt explosion" (when the outflow of a foreign investment surpasses the inflow of fresh capital). Foreign investors are often interested in participating in joint ventures with national enterprises in order to obtain an assured supply of fish. Such capital can participate by cash investment or through credits payable with a percentage of the production. A future way for private foreign participation could be through mixed capital enterprises or, if the case permits, through multinational enterprises.

Multinational ventures are a new concept not yet defined. For some countries the "multinational" concept depends on the need to cover markets of more than one country (USA). For others it depends on the composition of capital (Western Europe). In the case of the Andean Pact in South America, the multinational scheme is directly dependent on regional sources of capital which means that capital from countries other than those of the Pact is from a foreign source, not a "multinational" source.

Multinational ventures are most compatible with the nature of fishery activities since the products come basically from the seas and are marketed all over the world.

Credits from suppliers of equipment — This source of foreign funds for fishery development has some limitations. First, it is necessary for suppliers to adapt their equipment to the real technical needs of the project. Secondly, the financing conditions of such credits must be in accordance with those of the international capital market. The first aspect involves the risk that a supplier might provide inadequate equipment, which could be done in good or bad faith. There are many cases of project failure because of this. Financing of such credits is normally supported by policies of the supplier's government to encourage the export of capital goods. The conditions of acquiring the credits often involve not only rates of interest, commissions and terms, but requirements or components of technical assistance, shipping obligations, royalties, supply of parts and other aspects which, in total, may be more expensive than normal financing.

Resources from bilateral agreements — This source of foreign funds is increasingly replacing the credits of private suppliers. Bilateral financing agreements are normally made between governments and have the advantage that they can provide global amounts which can be used with flexibility according to the requirements and possibilities of each party. As these are credits negotiated between governments, they do not have the same limitations as the two previously mentioned sources of funds. Moreover, the countries can negotiate with whomever they please. The flexibility of this kind of agreement is such that it is even normal to use or to pay the credit in a currency of a third country which is not a party to the agreement.

Resources from multilateral agencies — These funds have two main characteristics: (i) they come from multilateral sources, (ii) they are utilized under technical criteria and policies basically independent of individual interest and free of bias on the part of contributors or beneficiaries. Multilateral resources are administrated by international financial agencies, such as the World Bank group and the regional development banks. These have the same structure as regular banks for the acquisition of capital funds but have the philosophy of development agencies as far as lending money is concerned.

Their resources can be divided into two groups: the "hard funds" and the "soft funds." The former are loaned under similar conditions to those existing in international capital markets, but for longer terms and with convenient periods of grace. The latter enjoy very favourable conditions concerning the rate of interest, commissions, length of time for payment and period of grace. A larger proportion of the total cost of the project can also be financed through them.

Multilateral resources are essentially oriented to those projects which require very special conditions. Hard funds are normally channelled to projects with an acceptable internal rate of return, and to countries with a better economic and financial position in terms of national income and foreign trade. Soft funds are used for projects of high social impact even if their economic internal rate of return is limited. A high priority is given to less developed countries. Thus there are no hard-and-fast rules or policies relating to financial conditions for fishery development projects. An investment project for artisanal fisheries could obtain soft funds if the social impact is important and the country justifies it. A project for a new fishing port can receive hard or soft funds depending on the specific conditions involved within the context of the country concerned.

Perhaps the most relevant advantages of the multilateral financing for fishery development are that it: (i) gives to the borrower the widest flexibility to select the suppliers of capital goods and technical assistance; (ii) permits the financing of integrated projects involving different areas of investment with diverse financing conditions; (iii) forces the countries to adopt modern and dynamic institutional structures to manage efficiently their investment projects and their fishery development.

Mechanics of Multilateral Financing

The financing of a fishery development project within a multinational agency involves the following stages: preidentification, identification, preparation, analysis, execution, control, and evaluation. These seven steps can be grouped in three: preinvestment, analysis, and execution.

Preidentification — The first step is to detect a possible investment area, normally the result of scientific research. This has been the great significance of FAO involvement during the past 25 years. The preidentification stage also helps to determine some of the major difficulties or limitations that could occur in the future project.

Identification — A project is considered identified when (i) it has been technically and economically defined, and (ii) when it has been given a priority in the national development policy.

Preparation — Once the previous steps are completed, it is possible to prepare the "investment project" according to the technical guidelines for a "bankable" project, with the necessary technical and economic details.

The Guide for Fishery Development Projects of the Inter-American Development Bank, for example, states that the following basic aspects be considered for project preparation: (a) summary of the loan application, (b) legal and institutional aspects, (c) borrower and executing agency, (d) technical description of the project (details in annexes), (e) the execution of the project, and (f) justification of the project.

Project analysis — The analysis of the project involves the technical appraisal and the financial, economic, institutional, and legal analysis. This is perhaps the most delicate and crucial step during the whole process and it requires very close communication between the analysts in order to arrive at coordinated conclusions. For fishery projects, the technical analysis is essential and precedes all the others because it must define the basis to be used by the other analysts. The analysis not only appraises the feasibility and merit of the project but can also suggest modifications and additions. It is also essential to determine the financial conditions under which the project can satisfactorily operate.

Execution of the project — Normally, this stage follows a predetermined schedule of investment which indicates the necessary funds required to implement the project. The borrower has to make the effort to implement the various stages of the project in an orderly way to achieve the desired results. Adequate management and necessary technical assistance are of prime importance.

Control — The financing agencies have available technical and accounting systems of control of the part of a project to be financed. These controls not only refer to the external aspects but also to the sequence of the design basis for its execution. With adequate control, the borrower can organize the use of the funds, detect the necessity for any technical or financial changes and introduce them.

Evaluation — Normally, this stage continues through the execution of the project and its following operations. Its purpose is to determine if the projections and goals of the project have been fulfilled. The evaluation process is most significant because the conclusions are based on experience and are very useful in the consideration of future projects, both for the borrower and the financial agency.

Reconciling Conflicts among Different Economic Interest Groups in the Management of Fisheries[1]

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MacKenzie, W. C. 1973. Reconciling conflicts among different economic interest groups in the management of fisheries. J. Fish. Res. Board Can. 30: 2065–2069.

It is argued that the combined interests of consumers, producers, and the public are best served if the benefits from and the costs of using available fishery resources are calculated in social terms. An optimal level of productive inputs to a fishery can be approached through the imposition of appropriate controls by the state. The form that such action might take in the case of established fisheries, particularly, is considered and the need for gradual and flexible implementation, to prevent industrial and social disruption, is stressed.

Management of international fisheries is complicated by the fact that the social optimum, which serves to provide a rational objective for one country, is indeterminate when fish stocks are exploited by fleets of several nations. A second-best arrangement, which would permit the purchase of inputs from the least costly sources and the sale of products in the markets where prices are highest, with the net proceeds being distributed among countries on the basis of need, seems to be impracticable in the foreseeable future. The conclusion is drawn that, for the present, a system of annual catch quotas allocated among interested countries may offer a reasonable solution to the problem.

The difficulties associated with the setting of quotas and their equitable allocation are discussed in some detail and the conflicts of interest that may arise in the process are indicated, e.g. those relating to variation in national time-preferences, to differences in stages of development, and to the accommodation of new entrants. Reference is made, in particular, to the conflict between the short-run interests of states with mobile (distant-water) fleets and those of coastal states. Some possibilities for the reconciliation of these conflicts are suggested, e.g. quota-share trading, compensation for abstention, and exchange of (fleet and port) services.

L'auteur estime que, pour servir au mieux les intérêts combinés des consommateurs, des producteurs et du public les avantages dérivant des dépenses consacrées à l'exploitation des ressources halieutiques disponibles doivent être évalués en termes sociaux. L'imposition par l'Etat de contrôles appropriés permet de s'approcher d'un niveau optimum d'apports productifs dans une pêcherie. L'auteur examine la forme que cette action peut revêtir dans le cas des pêcheries existantes et il souligne la nécessité d'une application progressive et souple, pour empêcher des effets perturbateurs dans le domaine industriel et social.

L'aménagement des pêches internationales est compliqué par le fait qu'il est impossible de déterminer un optimum social qui puisse servir d'objectif rationnel à un pays quand les stocks sont exploités par les flottilles de plusieurs nations. Comme pis-aller, on pourrait envisager un arrangement qui permettrait d'acheter les facteurs de production aux sources les moins coûteuses et de vendre les produits sur les marchés où les prix sont les plus élevés (le bénéfice net étant distribué entre tous les pays sur la base de leurs besoins), mais un tel arrangement semble impraticable dans l'avenir prévisible. L'auteur conclut que, pour l'instant, on peut apporter une solution raisonnable à ce problème en fixant pour les prises annuelles des contingents répartis entre les pays intéressés.

Il examine les difficultés liées à la fixation des contingents et à leur répartition équitable et il indique les conflits d'intérêts qui peuvent naître à cette occasion, par exemple ceux qui résultent des préférences différentes des pays en ce qui concerne les époques de pêche, des stades de développement inégaux et de la nécessité d'accueillir de nouveaux venus. Il mentionne particulièrement le conflit existant entre les intérêts a court terme des pays qui possèdent des flottilles mobiles (pêche hauturière) et ceux des pays côtiers. Il suggère certaines mesures pour concilier ces intérêts divergents, par exemple contingentement des échanges commerciaux, indemnisation en cas d'abstention et échange de services maritimes et portuaires.

Se dice que la mejor forma de servir los intereses de los consumidores, los productores y el público es calcular en términos sociales los beneficios derivados de los costos necesarios para aprovechar los recursos pesqueros disponibles. El problema del grado óptimo de insumos productivos dedicados a una pesquería puede resolverse mediante la imposición de controles adecuados por parte del Estado. Se examina la forma

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que esta intervención puede adoptar en las pesquerías establecidas y se insiste en la necesidad de una aplicación gradual y flexible, para impedir quebrantos industriales y sociales.

La reglamentación de las pesquerías internacionales se ve complicada por el hecho de que una finalidad óptima desde el punto de vista social, que puede constituir un objetivo racional para un país, se transforma en algo indeterminado cuando quienes explotan las poblaciones son flotas de varios países. Otra solución, que consistiría en adquirir los insumos en las fuentes donde sean menos costosos y vender los productos en los mercados donde los precios sean más altos (distribuyendo los beneficios netos entre los países según su necesidad), parece impracticable en un futuro previsible. Se llega a la conclusión de que tal vez la única solución razonable de este problema por el momento sea el empleo de un sistema de cupos anuales de captura, por países.

Se examinan las dificultades que lleva consigo el establecimiento de cupos y la asignación equitativa de los mismos y se indican los conflictos de intereses que puedan surgir en el proceso, por ejemplo debido a la diversidad de preferencias cronológicas de los países, a las diferencias en el estado de desarrollo, y a la admisión de los recién llegados. Se alude en particular al conflicto entre los intereses a corto plazo de los estados con flotas móviles (de gran altura) y los de los estados costeros. Se sugieren algunas posibilidades para resolver estos conflictos, por ejemplo venta del cupo correspondiente, compensación por abstención, e intercambio de servicios portuarios y a la flota.

Basic Concepts

For purposes of the discussion in this paper it is assumed that, in the use of fishery resources, "rationalization" or the achievement of economic efficiency is a major objective of management policy. Experience in the implementation of programs directed to that end is relatively meagre and, for that reason, the treatment of the subject here is pretty largely a priori.

In society generally, with reference to the design of an appropriate resource-management regime, three separate interests may be distinguished, namely those of resource owners (normally the general public in the case of fishery resources), producers, i.e. the fishing industry and the fish trade, and consumers. It is possible to conceive of regulatory systems that would maximize benefits for each of these groups, at the cost of the others, such benefits being represented by resource rent, intramarginal factor rents (producers' surplus), and consumers' surplus, respectively.

Like the nonmaximizing free-entry system, i.e. in most instances the traditional fishery-management regime, none of the conceivable systems just mentioned can be considered socially optimal. In terms of steady-state equilibria, the social optimum is attained when the marginal social revenue from a fishery equals the marginal social cost of the fishery. At that point[2] the net social benefit, i.e. the combined total of resource rent and producers' and consumers' surpluses, is maximized – and, in theory at least, divergence in interest among the groups referred to is minimized.

The conditions necessary for achievement of the optimum are quite well known. Adjusted for imperfections in factor and product markets, productive capacity in a fishery should not exceed the level at which the difference between aggregate revenue (the gross yield in value terms) and total harvesting costs is at a maximum. [3]This involves restriction of inputs of capital and labor in a fishery, a function that ordinarily must be exercised by an external authority – presumably the state in most cases.

Management in One Country

In the usual case, intervention by regulatory authority comes late, when the signs of distress (capital losses and the like) resulting from "overfishing" are visible in acute degree. That is, the problems to be solved relate not so much to preventing the emergence of excess capacity or fishing power as to the restoration of economic efficiency in a fishery.

General Principles

In a young fishery, exploiting a previously unused stock, extraordinary catches and "abnormal" profits frequently are made. A powerful incentive is thus created for the entry of additional enterprises and, for a time, the total stock yield (catch) may rise more or less in proportion to the increase in input. As the fishery matures, however, the intensification of operations affects the size and age structure of the stock: yield and earnings decline and ultimately, unless and until the fishery adjusts to the new situation, revenue may fall below costs.

The process of short-run adjustment tends to be very unstable. At the start the maximum sustainable yield of the stock is unknown and the biological reactions to exploitation are manifested only gradually. In an unregulated competitive fishery, consequently, the expansion of operations tends almost inevitably to overshoot sustainable yield. As a result, the presence of excess productive capacity, and of the "locked-in" capital and labor associated with it, is generally pervasive in mature fisheries.

For the producers involved, therefore, particularly the primary producers (fishermen), the transition to a regime of rational management may be especially traumatic.

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[2] Biological and economic factors both being subject to constant change, of course, "equilibrium" represents not a fixed point but a condition toward which a fishery and the exploited stock(s) tend.

[3] Apart from political and institutional obstacles to the imposition of charges for access to fishery resources (traditionally free to users), the practical difficulties encountered in the execution of a rational fishery-management program relate primarily to the determination of an appropriate quantum of inputs for a specific fishery. Since the critical elements in the calculation appear to be an estimate of the opportunity costs of production factors and measurement of the technical efficiency of fleet units, these difficulties should not be insurmountable.

Repercussions from a (temporary) shortening of supply may bring about profound disturbance in the processing and marketing sectors also during the transitional phase – and the restoration of stability may be prolonged over periods of varying length. Since conflicts of interest arising from a situation of this nature may be exacerbated by the type of regime or the set of institutional arrangements adopted for the transition, the design of the latter becomes extremely important.

Theoretically, the levying of a tax or royalty on the catch seems to be the most effective method of fishery rationalization. By this means, the revenue of fishing enterprises (for a given catch) is reduced in proportion to the rate of the levy, thereby reducing the private return per unit of catch and inducing the fishery to reach equilibrium at a level of input consistent with the social optimum. This result would not be fully realized, however, if incidence of the royalty were shifted by an imperfect port market. Moreover, notwithstanding the potential long-run gains from an increase in the productivity of inputs, the immediate effect of imposing such a charge may appear to be simply a rise in the costs of fishing. In certain circumstances, including the presence of a fleet of homogeneous fishing enterprises, a graded and progressive license fee, appurtenant to vessels or to operators, might be equally effective – provided the resource rent is thereby appropriated.

The desirable criteria that an approach to rationalization should satisfy include: a) that it not contribute to distortion of inputs, or of the techniques applied, in a fishery; b) that it not diminish incentives for the adoption of improved technology; c) that it be capable of being imposed at varying rates for different grounds and seasons, in the interest of efficient resource management; d) that it be capable of being imposed gradually, to minimize industrial disruption; and e) that it not discriminate against any unit of the fishing fleet involved, regardless of the heterogeneity of the latter.

The last two points are especially significant if, for example, the maintenance of employment opportunities for immobile fishermen is an objective of management. Among the ranks of these are found many part-time and semirecreational fishermen, whose production often is obtained at lowest cost in real terms and whose exclusion from the fishery would be socially wasteful. Also, in particular during the transitional process, minimization of compulsion and of hardship for those established in an overcrowded fishery requires that the fullest advantage be taken of the normal retirement patterns of fishing craft and crews and of voluntary methods of withdrawal.

Techniques of Control

Fisheries differ variously one from another and the conflicts of interest as well as other problems presented may be to some extent unique to each. It is unlikely, therefore, that any management regime would be completely applicable in every case at all times. An approach that may have fairly general applicability is outlined below.

Initially, in a highly labor-intensive fishery, fishing rights might be confirmed (by license or entry permit) for all established and active participants. In this way social dislocation during the transitional phase would be minimized. Because of the age structure typical of the labor force in many fisheries, attrition of numbers might be rapid enough. Physical-asset losses, assuming a normal market for craft and gear, might be minimized by avoiding restrictions on the fishing power or capacity of fleet units at this time.

For a relatively capital-intensive fishery, the prescription probably would be different. In this case, often characterized by rapid labor turnover, protection of the investment may be the primary consideration and confirmation of continued access for the vessels engaged the first requirement. Administrative problems relate chiefly to the specialization of fishing craft and their rate of obsolescence. The necessary reduction in capacity might be facilitated through institution of a program for the purchase and retirement of vessels by the management authority.

The incomes of fishermen, both crew and vessel owners, should increase significantly over the period of transition – and, among other things, demonstrate the emergence of resource rent in the fishery. At some point an initial resistance to a public share in the returns from the fishery may be relaxed and at that point a catch royalty or, if appropriate, a plan of restricted licensing could be introduced. It is important that the royalty or license fees extract the bulk of resource rent: to the extent that this rent accrues to fishing enterprises, the owners are provided with an incentive to expand capacity beyond the optimum, and thus private and public interests fail to be reconciled.

The increase in incomes resulting from fishery rationalization contributes to the financial independence of the vessel owners. A system of licenses appurtenant to operators, therefore, would tend to prevent concentration of fleet ownership and control – if that is a desired objective. Vertical integration, on the other hand, might be encouraged under certain conditions by a system of vessel-appurtenant licensing. Decisions in matters of this kind probably depend as much on the objective conditions surrounding particular fisheries as on social philosophies.

With contraction of fleet capacity toward the optimum, restrictions on the gear used and seasonal closures imposed to control output could be lifted, thereby not only enhancing input productivity but also removing a common source of conflict in the commercial fisheries. The incentive, provided by rising incomes, to remain in a fishery under rational management should reduce the danger of men and equipment being transferred to other fisheries and aggravating congestion therein.

Management of International Fisheries

So far the discussion has dealt with the problem under consideration from the internal viewpoint of a single nation-state. Nevertheless, it is thought to have some relevance, *mutatis mutandis*, in a broader context. The extension of rational management to international fisheries, however, is subject to peculiar difficulties.

Special Aspects of the Problem

When a fishery is prosecuted by fleets of different countries, product prices and the opportunity costs of production factors may differ widely among them. In such a case, therefore, the socially optimal catch is indeterminate. With different relative valuations placed on capital, labor, and output, the participating countries would be impelled to make different choices among alternative possibilities as to fishing intensity and catch composition: some favoring large volume, for example, others opting for large (older) fish, and still others for a competitive species. Such conflicts of interest, stemming from differences in national income and tastes, may extend as well to noncommercial objectives of fishery management.

A second-best solution to the international management problem would involve "internationalization" of the fisheries requiring conservation under an institutional arrangement (multinational corporation or the like) that would seek to approximate the optimum by applying the cost function of the country with the lowest opportunity costs for production factors and the demand function of the country where prices for the derived product(s) are highest. The arrangement would serve to maximize welfare if net proceeds were distributed internationally in accordance with need.

Variations of this arrangement, e.g. turning over the profits to FAO (as representing the international community), say, or awarding client nations an equity share in profits, although more distant departures from the optimum, might still be admissible. The trouble is that irrationality in national resource-management policy and practice is liable to be compounded on the international scene. In advanced as much as in developing countries, maximization of economic efficiency (even broadly interpreted) may be superseded at times on the priority list of management objectives. This, together with the cession of national sovereignty implied in such arrangements, indicates their probable impracticability in the foreseeable future.

A PRACTICABLE APPROACH

The best that can be hoped for at present, assuming agreement on the need for conservation[4], is the establishment of catch quotas[5] for fish stocks under international exploitation and, based on some suitable formula, the allocation of shares in such quotas among participating countries. The latter step is necessary to avoid a competitive scramble for supply and an accompanying waste of society's resources equal to that which would occur in an unrestricted fishery. With assurance of a predetermined share in the catch, each country is in a position to adopt the management policy that accords with its own social goals.

The type of mechanism through which annual catch quotas are set and national shares allocated in international fisheries is irrelevant to this discussion: one may assume continuation of the existing mechanisms or hypothesize others evolving in the future. The conflicts of interest to be resolved are unlikely to differ greatly in any event.

It is generally agreed that, as far as possible, catch quotas should be established separately for discrete stocks or populations and that, when required, ground and "global" quotas should be constructed on that basis. If this is impracticable, as, for example, when there is much intermingling of exploited species, a more generally based quota supplemented by seasonal closures may be sufficiently effective. Seasonal closures also might be applied to control effectively the distribution of fishing operations (from the resource-management viewpoint) between heavily exploited stocks or grounds and underexploited ones within a single operational and management area.

The establishment of quotas on a stock basis does not imply a bias in favor of institutional arrangements on that basis. On the contrary, the interdependence of competing fish stocks and food supplies suggests the necessity in general for management encompassing broad regional ecologies, to permit the use of preferred stocks being regulated in harmony with competitive and complementary life forms.

Ideally, perhaps, annual catch quotas in most cases should be set somewhat below estimates of maximum sustainable stock yield in physical terms. Forms of the latter concept, however, despite its ambiguity where competitive or predatory relations occur among exploited species, are deeply entrenched in existing institutions of international fishery management. A move to replace them, however well intentioned, would be provocative and, in view of the crudity of the materials (if not the tools) for quantitative analysis in resource management,[6] hardly worthwhile.

Acceptance of this concept, nevertheless, tends to complicate international agreement on management programs. Countries with relatively low rates of time-preference, for example, may be reconciled easily to the abstention necessary for the restoration of a stock of fish to its pristine state – more impatient countries may not. There also may be objection to the concept on the ground that a depleted stock is replaceable by that of another species of equal or greater value. In general, however, the concept probably is acceptable as a convenient approximation of optimum yield.

PARTICULAR CAUSES OF CONFLICT

The setting of quotas may bring to the surface a conflict of interest between countries whose catch from the stock(s) involved is on the increase or, for some reason, may be expected to increase, and those whose catch has been declining. This difficulty might be overcome through an arrangement for trading quota shares or providing compensation for the relinquishment of claims to shares or both.

A similar arrangement might be helpful in the case of new entrants in a fishery under conservation. Since national shares are likely to be related to historical involvement, potentially interested countries and even those with but a short history in the fishery may find the system unfair. On the other hand, if additional entrants were admitted without restriction, the shares of countries with "historical rights" would diminish progressively. Shares ultimately would tend to become uneconomic in size and one nation after another would be forced out of the fishery.

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[4] Disagreement may relate mainly to timing: because of market requirements, for example, some countries are much more quickly affected than others by the alteration in the size composition of catches resulting from intensification of fishing.

[5] An alternative system, that of input or "effort" quotas, is also conceivable but presents horrifyingly complex difficulties of administration.

[6] Economic forecasting (of price trends, etc.) probably is even less precise than stock assessment, for example.

A further problem pertains to the administration of a system of national quota shares. If the size of the aggregate annual quota for a controlled fishery is subject to uncertainty from year to year, as, being based on an estimate of sustainable yield per recruit, it well may be, the quantity actually taken by a particular fleet may depend directly on the extent of national input. In this situation, and especially if total fleet capacity substantially exceeds the quota (a not uncommon case), some or all of the participating countries would have a strong motive for excessive input, i.e. overentry. Unless all countries restrict entry, however, it may be very difficult for any to do so. The objective of those that would rationalize their participation in the fishery thus would be defeated.

Finally, establishment of a quota-sharing system leaves unsettled the problem of interference and friction between fishing fleets. More particularly, although by no means exclusively, of international incidence, the reference here is to the vulnerability of stationary fishing gear to damage by towed gear. In certain circumstances, the former type may be the more efficient economically and its obstruction results in a social loss. Again the problem is amenable to minimization, at least, through appropriate and adequate enforcement procedures applied internationally.

COASTAL VS. DISTANT OPERATIONS

It is in respect of details of this kind that the disparate interests of mobile fishing fleets and relatively immobile ones, or, amounting to much the same thing, those in the short run of countries with distant-water fishing fleets on the one hand and coastal states on the other, are brought into sharpest focus. A system of quotas, considering the deficient predictability of year-class abundance and the like, may work to the disadvantage of fleets that cannot shift operations readily from one location to another. It is futile, for example, to allocate to Canada a share in the quota for cod on Hamilton Bank (off Labrador) if that country's fishing industry does not have vessels sufficiently large and powerful to exploit the stock there. The less mobile fleets are placed at a disadvantage particularly if fishing intensity must be decelerated rapidly – which suggests that, like purely national regimes, international fishery-management arrangements should provide for gradual implementation.

The advantage of mobility is most obvious, of course, when quotas embrace several stocks and especially when movement is possible to more than one management area. Vide, for example, the world-wide operations of some elements of the fleets of Japan and the USSR (and the reference here is not to "raid" fishing) giving rise to the conclusion that all regions frequented by the same fleets should be under one management. This advantage is capable of realization largely because of the existence of factors external to the commercial fisheries, e.g. impediments to the international movement of goods and services – implying a less than optimal allocation of the world community's supply of social resources. Consideration of foreign trade and exchange adjustment, however, is felt to be beyond the proper scope of the present paper.

It is probable that, other things being equal, near-water fishing is inherently more efficient economically than distant-water fishing. A rather widespread source of international discord might be eliminated, therefore, and progress toward optimal resource use advanced, if countries that consider their interests as being essentially those of coastal states were prepared to trade off any stake they may have acquired, or may anticipate developing, in distant-water fishing in return for recognition by other countries of their special concern for the rational management and efficient utilization of the fishery resources in the waters adjacent to their shores.[7]

The concern is rooted in the dependence of regional economies, and indeed of at least one national economy, on the productivity of these resources being maintained. This concern is matched, on the part of countries with distant-water fishing interests, by a need to secure adequate supplies of animal protein and/or to earn a satisfactory return on major investments in fleets, port facilities, and infrastructure. The resulting clash of interests probably is the fundamental issue confronting international fishery management. The conflict is not necessarily irreconcilable. Aside from the common long-run interest in resource conservation, coastal states may benefit from the operations of mobile fleets offshore, e.g. as a result of emulative technical innovation in the domestic fleet and business expansion locally on the basis of services to the foreign fleets and/or foreign installations ashore.

The intention here, assuming effective mechanisms to exist for the resolution of conflicts, has been to indicate the objectives that should be pursued and to suggest a few of the ways and means by which these objectives might be achieved.

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[7] In the special case of anadromous species, coastal states' right to the harvest – based on investment in maintenance and enhancement of the stocks – might be secured through compensation of the international community for access to high-seas "pasturage."

License Limitation Regulations: Canada's Experience[1]

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In the late sixties, Canada introduced legislation to provide for the limitation of fishing licenses in two specialized fisheries — the lobster fishery of the Atlantic coast, and the salmon fishery of the Pacific coast. These regulations were introduced for economic and not conservation reasons.

As a result of the limitation program the number of licensed salmon vessels in British Columbia had been reduced from 7548 in 1968 to 5890 in 1972. The program called for salmon vessels to be grouped into two categories based on their record of production in 1967 or 1968. Vessels with low production ("B" category) can continue in the salmon fishery for only 10 years. License fees for "A" category vessels have been increased sharply. New salmon vessels can only be licensed provided an equal tonnage of "A" category vessels is retired from the commercial fishery. The Government is using the money from licenses to purchase from fishermen active salmon vessels and retire them from the fishing industry. Indians have been given the special privilege, for social reasons, of obtaining salmon licenses for their vessels at minimum cost, but they still cannot license a new vessel unless an equivalent tonnage of vessels has been retired. The average value of individual salmon vessels remaining in the fleet has increased substantially and the higher values are not justified in relation to the increased returns that can be achieved because of the fewer number of fishing vessels. The final phase of the plan is under review by an industry committee charged with making representation to the Government in 1973.

In the Maritime Provinces the limitation program for lobster boats has not progressed as quickly as the salmon program in British Columbia. A base, however, has been established: vessels have been divided into "A" and "B" categories but no action had been taken up to September 1972 to limit the life of "B" category lobster vessels. Until this is done, or other means taken to reduce the fleet, very little reduction in the number of boats is expected.

These limitation programs, for what are essentially small boat fisheries, are unique, since few attempts have been made in the world's fishing communities to control the number of vessels for economic reasons. The progress of these programs will provide administrators and economists with criteria for future management.

Vers la fin des années soixante, le Canada a introduit une législation limitant les permis de pêche dans deux pêcheries spécialisées: la pêche au homard sur la côte Atlantique et la pêche au saumon sur la côte du Pacifique. Cette réglementation a été introduite pour des raisons économiques et non pour conserver les ressources.

L'introduction de ce régime restrictif a fait tomber le nombre des bateaux détenteurs de permis de pêche au saumon de 7548 en 1968 à 5890 en 1972, en Colombie britannique. Ce régime prévoit que les bateaux de pêche au saumon seront groupés dans deux catégories, sur la base du chiffre de leurs prises en 1967 ou 1968. Les bateaux ayant une faible production (catégorie "B") peuvent continuer à pêcher le saumon pendant 10 ans seulement. Le coût du permis pour les bateaux de la catégorie "A" a été fortement majoré. Des permis ne peuvent être accordés à de nouveaux bateaux pour la pêche au saumon que si un tonnage égal de bateaux de la catégorie "A" est retiré de la pêche commerciale. Les autorités utilisent les droits perçus sur les permis pour acheter aux pêcheurs de saumon des bateaux encore en service, qu'elles retirent ensuite de l'industrie des pêches. Un statut privilégié a été accordé aux Indiens pour des raisons sociales: ils peuvent obtenir des permis de pêche au saumon moyennant le versement d'une redevance minimum, mais ils ne peuvent quand même pas obtenir un permis pour un nouveau bateau si un tonnage équivalent n'a pas été retiré. La valeur unitaire moyenne des bateaux de pêche au saumon qui restent dans la flottille a augmenté sensiblement et

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

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leur valeur accrue n'est pas justifiée par rapport à l'accroissement des gains réalisables à la suite de la diminution du nombre des bateaux de pêche. La phase finale du plan est étudiée par un comité qui est chargé de présenter ses observations en 1973.

Dans les provinces maritimes, le programme tendant à réduire le nombre des bateaux de pêche au homard n'a pas progressé aussi rapidement que celui qui visait le saumon en Colombie britannique. Une première mesure a toutefois été prise: les bateaux ont été divisés en deux catégories "A" et "B," mais rien n'avait été fait jusqu'en septembre 1972 pour limiter la durée de service des bateaux de pêche au homard de la catégorie "B." Tant qu'il en sera ainsi ou tant que la flottille n'aura pas été réduite par d'autres moyens, le nombre des bateaux de pêche diminuera sans doute très peu.

Ces programmes restrictifs, qui portent essentiellement sur de petits bateaux de pêche, sont particulièrement remarquables car les tentatives faites dans les pêches mondiales en vue de limiter le nombre des bateaux pour des raisons économiques sont très rares. Le déroulement de ces programmes donnera aux administrateurs et aux économistes des indications pour l'aménagement futur.

A finales de los años sesenta, Canadá introdujo una legislación para limitar las licencias de pesca en dos pesquerías especializadas: la de bogavante de la costa atlántica y la de salmón de la costa del Pacífico. Estas normas fueron motivadas por razones económicas, no por el deseo de conservar los recursos.

Como consecuencia del programa de limitación, el número de embarcaciones autorizadas para la pesca del salmón en Colombia Británica ha disminuido de 7548 en 1968 a 5890 en 1972. El programa pedía que se agruparan las embarcaciones salmoneras en dos categorías, según su producción en 1967 o 1968. Las embarcaciones con poca producción (categoría "B") sólo pueden continuar en la pesquería del salmón por 10 años. Las tarifas para la concesión de licencias de la categoría "A" han aumentado notablemente. Sólo es posible conceder licencias a nuevas embarcaciones salmoneras a condición de que se haya retirado de la pesquería comercial un tonelaje igual de embarcaciones de categoría "A". El Gobierno utiliza los fondos derivados de la concesión de licencias para adquirir embarcaciones salmoneras aún activas y retirarlas de la industria pesquera. Por razones sociales se ha concedido a los Indios el privilegio especial de obtener licencias para la pesca del salmón a costo mínimo, pero incluso en este caso no es posible conceder licencia para una nueva embarcación a menos que se haya retirado de la pesquería tonelaje equivalente. El valor medio de las embarcaciones salmoneras que permanecen en la flota ha aumentado notablemente, sin que baste para explicarlo el incremento de los beneficios que es posible conseguir al ser menor el número de embarcaciones pesqueras. Actualmente, un comité de industria, encargado de exponer sus conclusiones al Gobierno en 1973, está examinando la fase final del plan.

En las provincias marítimas, el programa de limitación de las embarcaciones dedicadas a la pesca del bogavante no ha avanzado con tanta rapidez como el programa salmonero en Colombia Británica. De todas formas, se han puesto ya los cimientos, dividiendo las embarcaciones en categoría "A" y categoría "B," pero hasta septiembre de 1972 no se había adoptado ninguna medida para limitar la vida de las embarcaciones de categoría "B." Hasta que se haga esto, o se tomen otras medidas para reducir la flota, no se espera que el número de embarcaciones disminuya en forma apreciable.

Estos programas de limitación aplicados a pesquerías que son esencialmente de embarcaciones pequeñas, son únicos en el mundo, ya que son pocos los intentos hechos en las comunidades pesqueras mundiales por controlar el número de embarcaciones por razones económicas. La marcha de estos programas permitirá a los funcionarios administrativos y a los economistas disponer de criterios para la reglamentacíon del sector pesquero en el futuro.

In the late 1960s, the Federal Government of Canada introduced programs to limit licenses in the lobster fisheries in the Maritime Provinces on the Atlantic coast and in the salmon fisheries in British Columbia on the Pacific coast.

The east coast lobster limitation program was introduced in 1966. The Salmon Vessel License Control Program on the west coast followed in 1968, but in the period since it was introduced has progressed faster than the lobster licensing program on the east coast.

British Columbia Salmon Vessel License Control Plan

The west coast program has been continually assessed since its introduction and provides an excellent example of the economic impact of government regulations on capital investment, employment and increased returns. For this reason the major emphasis of this paper will deal with the salmon vessel license control plan in British Columbia.

B.C. Fishing Industry

A general knowledge of the background of the fishing industry in British Columbia is necessary to appreciate the need for a salmon license limitation program and to assess its success.

The fishing industry in British Columbia, in common with the west coast states of the United States — Washington, Oregon, and Alaska — is dominated by salmon. In British Columbia, salmon account for between 70 and 75% of the total value of all fish landed and marketed. Salmon runs in British Columbia have been fully exploited since the mid-1930s. To ensure adequate spawning escapement and thus the continued maintenance of stocks the total catch of each species of salmon each year in every area has to be controlled either by reducing fishing time, by gear restrictions or by other types of restrictive regulations.

During the past 20 years, the commercial salmon catch by the three types of commercial gear — seiners, gillnetters, and trollers — has ranged between 12 and 35 million salmon. Fishermen with these gears operate in specific areas along the coast through which the salmon pass on their migration routes to spawning grounds located in more than 1600 freshwater rivers and streams in the province.

There are five species of salmon landed in British Columbia. Two of the five — coho and chinook during the period they are maturing — can be caught by trollers. The other three species — sockeye, pinks, and chums — are captured by gillnet and seine and to a limited extent by troll when they are no longer feeding but have schooled and are en route to their spawning rivers and streams.

Regulations to ensure adequate spawning escapement for salmon are most complex; they depend on the strengths of individual runs so are subject to weekly and daily changes during the fishing season. Many of the regulations dealing with specific gears were implemented initially and primarily to ensure adequate salmon escapement, but some have become accepted as historic rights for particular gear types. At one time regulations were based entirely on conservation needs but it is now necessary for the Department when considering regulation changes also to take into consideration the economic and social needs of fishermen and the fishing industry.

The problems of the fishing industry in British Columbia are accentuated by the fact that 65–75% of the salmon must be caught during the 10-week period when they are migrating. Only a small segment of the salmon fishing fleet can be usefully employed in other fisheries. From an economic standpoint, therefore, it is difficult to justify capital expenditure on boats and gear that is used for the most part less than a quarter of the year. Even during this 10-week period when most of the salmon are caught, gillnet and seine vessels are limited in their fishing periods from 2 to 5 days a week.

TABLE 1. Capital in primary industry related to landed value of fish in British Columbia.

Period	Average annual capital value			Average landed value of catch	Ratio of capital investment to value of catch
	Boats	Gear	Total		
		(Can.) $ '000		(Can.) $ '000	(Can.) $ '000
1883–99	191	152	343	1,842	1–5.37
1890–91	697	387	1,084	4,138	1–3.82
1900–09	1,329	728	2,057	6,783	1–3.30
1910–19	3,497	1,450	4,947	16,598	1–3.35
1920–29	6,640	2,099	8,739	12,690	1–1.45
1930–39	7,442	1,766	9,208	7,712	1–0.84
1940–49	14,976	3,350	18,326	20,112	1–1.10
1950–59	41,792	6,617	48,409	35,743	1–0.74
1960–64 (5 years)	61,957	9,649	71,606	42,120	1–0.58
1965–69	87,890	12,152	100,042	52,825	1–0.53
1970–71 (2 years)	106,885	15,818	122,703	59,421	1–0.48

Individual fishermen, in order to compete, have increased the size and speed of their vessels, have adopted new fishing techniques, and have invested in complex electronic equipment. All these changes have increased costs. Fish prices have also increased sharply, but despite this, the relation between capital investment in boats and gear and value of fish landed has shown a steady decline since the salmon industry was established in British Columbia in the late nineteenth century (Table 1).

In the early period of the fisheries of British Columbia (1883–89) fishermen realized an average of $5.37 (Can.) in gross returns for each dollar invested in boats and gear. By the 1940–49 period this dropped to $1.10 (Can.), 1970–71 period to 46 cents. At the same time operating costs, including interest rates, have increased sharply, and net returns from salmon fishing particularly has shown marked declines.

BACKGROUND OF LICENSE LIMITATION PROGRAM

The question of a license limitation program, for both salmon and halibut, had been under review by the Government of Canada for many years as a result of representations from fishermen's organizations.

In 1957 Dr Sol Sinclair, Economist of the University of Manitoba, was commissioned "to study the problems of the salmon and halibut fisheries towards evolving management practices and regulations that will permit economic operations within these two fisheries." (Sinclair 1960).

The "Sinclair Report," published in 1960, set out a number of specific recommendations on how these objectives might be achieved. The main recommendation included higher license fees, coupled with a moratorium on licenses for 5 years. After this 5-year time period had expired the Government would fix the number and type of licenses necessary to provide an economic harvest, and then this number of licenses would be disposed of by the Government under a competitive bidding auction. Once issued, licenses would be transferable between fishermen.

The report's recommendations met with an adverse response from all segments of the fishing industry. A small government committee was appointed to meet with industry groups to see if any of the recommendations would be acceptable. The Committee inquiry met with little success and industry groups cooled down in their attitude towards a limitation program.

In the mid-1960s the pressures for a license control program began to rebuild. In 1966 the annual licensing system in British Columbia was changed to licensing fishing vessels rather than fishing gear. Under the new licensing system, in addition to a fishing license a special salmon license was required which had to be obtained before May 31st of each year.

In the fall of 1966, the Minister of Fisheries, the Hon. H. J. Robichaud, announced that "no assurance could be given to any fisherman to license his vessel in 1967 if he had not operated his vessel in the salmon fishery in 1966 or did not have a vessel under construction." This was not a definite regulation and the proposal met with strong reaction from fishermen and as a result the proposed limitation program was redrawn 2 weeks later.

It became apparent to fishermen, however, that the government was seriously exploring the question of license control and it was not coincidental that construction of new salmon vessels boomed in 1967 and 1968.

SALMON VESSEL LICENSE CONTROL PROGRAM

It was not until September of 1968, however, that the political climate was right in Canada for implementation of a salmon vessel license control program. It is not feasible to present all the details of the British Columbia salmon program in this paper but a document has been published which outlines the limitation program from its inception to July of 1972 (Campbell 1972).

Some of the pertinent highlights of the program, however, need to be examined, as do the results that have been achieved in the short time it has been in effect.

The first phase of the program divided vessels into "A" and "B" categories based on salmon production in either one of 2 base years, 1967 or 1968. The "A" category vessels could be retired and replaced, whereas the "B" vessels with low production could not be reconstructed or enlarged and would gradually be eliminated from the salmon fishery by attrition. Salmon vessel license fees were increased sharply, but total revenue recoverable from the new scale of fees was still only a fraction of the costs associated with the administration of the salmon fishery in British Columbia. Vessels that were under construction at the time of the announcement (September 6, 1968) were given the privilege of obtaining a salmon license in 1969.

Reference has already been made to the record number of new salmon vessels built in 1967 and 1968 (Table 2). If the salmon vessel license control plan had not been implemented, construction would probably have eased off somewhat in 1969 and 1970, but not to the extent that it did.

TABLE 2. Construction of salmon vessels in British Columbia (1950–71).

Year	No.	Value	Avg
		$ '000 (Can.)	Can. $
1950–55 avg	141	1551	11,000
1950–60 avg	103	1241	12,049
1961–65 avg	186	2443	13,134
1966	126	2596	20,603
1967	217	4174	19,235
1968	210	4147	19,747
1969	149	3101	20,812
1970	121	2666	22,033
1971	99	2040	20,606

In the first phase of the Salmon Vessel License Control Program, as announced in 1968, it was necessary to retire a category "A" vessel in order to introduce a new vessel into the salmon fleet. In 1969, and until June of 1970, while this particular retirement provision was in force, small "A" category vessels (many less than 25 ft in length) were being used as replacements for larger salmon vessels. During this period these small vessels commanded a premium price on the market, and this price in effect was the value of a salmon license in a restricted market situation.

In June of 1970 the retirement provisions of the license control regulations were changed from a boat-for-boat basis to a ton-for-ton basis. This announcement resulted in an immediate decline in the market price for small "A" category vessels and at the same time had a direct influence on new salmon vessel construction. In 1971, only 99 new salmon vessels were constructed, the lowest number since 1958.

Up until 1968 the number of vessels equipped and licensed for salmon fishing in British Columbia remained fairly constant from year to year at between 7200 and 7600. About 90% of these vessels actually fished each year. Since the introduction of the Salmon Vessel License Control Program, the number of salmon vessels licensed has been dropping steadily each year (Table 3).

TABLE 3. Number of salmon vessel licenses (1967–72).

Year	Licensed for salmon	"A"	"B"	Number "A" vessels opting to "B"	Number vessels actually fishing salmon
1967	7639				6639
1968	7548				6603
1969	6931	5869	1062		6136
1970	6601	5641	960	46	6201
1971	6285	5322	963	178	5806
1972	5890[a]	4995	895	126	5526

[a] As of September 15, 1972. (includes 66 licenses for vessels under construction: licenses have been applied for but not issued.)

Between 1968 and 1972 the number of vessels licensed for salmon declined by 22% to 5890. Of the total number of salmon vessels licensed in 1972, 895 were "B" category with a maximum eligible salmon license period of 10 years from the time the vessel first became a "B" category.

In 1969 (the first year of the new program), increased vessel license fees and restrictive regulations associated with obtaining a salmon fishing license resulted in an immediate decline in the number of salmon vessels. Many of these that did not re-license in 1969 were "B" category vessels with only minimal commercial salmon landings.

MAJOR CHANGES

In 1970 and 1971, three additional major changes were made in the limitation plan. Each of these changes had a direct influence on the licensing of salmon vessels, and the effect of each of these changes should be examined.

(1) *In 1970, vessel license fees for salmon were doubled for all vessels except those under 30 ft (10 m).* When the initial control plan was announced in 1968 the Minister of Fisheries, the Hon. Jack Davis, gave notice that the salmon fee schedule would be reviewed annually with a view of increasing returns from the resource. After the poor salmon season in 1969, the Minister decided not to increase salmon license fees in 1970. In July of 1970 when it became apparent that a good salmon year was in the offing, Mr. Davis announced that salmon vessel fees in 1971 would be doubled for all vessels in excess of 30 ft.

This fee increase in 1971 resulted in a decision by 178 "A" category vessel owners to drop their vessels to the "B" category level. Many of those who opted for a lower priced license with a 10-year maximum life were older fishermen who apparently did not plan on continuing to fish beyond the expiring license period. Each one decided that it was not in his interest to pay the higher license fee during this period. The Minister of Fisheries in his annual review of license fees in 1971 decided that there would be no increase in the salmon license fees in 1972. An additional 126 "A" category owners dropped their vessels to a lower category in 1972.

(2) When Phase II of the program was announced, it included the proviso that *revenue from "A" category salmon license fees* would be used to purchase category "A" vessels and retire them from the West Coast fishing industry.

This buy-back program (as it is commonly referred to) did not start, however, until the spring of 1971, and by that time 2 years' license revenue had been accumulated. The fund is administered by a committee consisting of representatives of fishermen and fishing companies under the chairmanship of a Fisheries Service representative.[2]

A fisherman considering selling his vessel makes application to the Fisheries Service.[3] The vessel is then appraised on the basis of its estimated market value by two appraisers acting independently. These market values are averaged and a 5% bonus added as an inducement for the fisherman to sell to the Government rather than to a buyer in the private sector. Up until March 1972, about 1000 requests for appraisals had been received from fishermen who indicated they were interested in selling their vessels. As of the end of March 1972, agreement had been reached with 176 owners, and vessels valued at $2,442,000 (Can.) had been purchased by the Government. These vessels were sold at auction for $1,126,000 (Can.) which represented only 46% of their value as fishing vessels. Some of these vessels were exported; others were purchased to be modified and used for recreation purposes, while others were to be used for other industries such as logging.

The number of "A" category vessels licensed in 1972 was 395 less than in 1971, the Government "buy-back" program accounting for 176 of this number. The Government continued to purchase vessels after April 1, 1972, as new license fee revenue became available. Between April 1 and September 20, 1972, an additional 65 "A" category vessels, licensed in 1972 and valued at $1,310,600 (Can.), were purchased under the plan and retired from the commercial fisheries of British Columbia. Many of the vessels taken over by the Government between April 1 and September 15, 1972, were purchased prior to the fishing season, but to be eligible for "buy-back" had to have a valid 1972–73 fishing license. The total licensed salmon vessels shown for 1972 includes those 65 vessels purchased between April 1 and September 15, 1972.

Each year from 1968 to 1972 between 400 and 600 salmon fishing vessels changed ownership. As a result of the Government "buy-back" program the number of vessels coming into the market has been sharply reduced. The result has been an inevitable increase in the market value of fishing vessels in the private sector.

In 1970 and 1971, prior to the introduction of the "buy-back" plan, vessel market prices as reported by fishermen at the time of licensing reflected increases that were based on the cost of new vessel construction plus the cost of acquiring the necessary tonnage to retire and build a new vessel.

In 1972 the estimated total market value of all salmon vessels increased by 6.8% over 1971 despite a decrease of 5.8% in the number of salmon vessels licensed. Increased

TABLE 4. Average value of fishing vessels by type (1971-72).

	Average value per vessel			Average value per ton		
	1971 Can.$	1972 Can.$	% Change	1971 Can.$	1972 Can.$	% Change
Drum seine	46,751	52,847	+13.0	1218	1357	+11.4
Table seine	74,377	72,352	− 2.8	1089	1073	− 1.5
Table seine	74,377	72,352	− 2.8	1089	1073	− 1.5
Gillnet	6,772	8,189	+20.9	1254	1451	+15.7
Troll	15,413	17,347	+12.5	1653	1831	+10.8
Gillnet-troll combination	14,409	16,180	+12.3	1696	1906	+12.3
All vessels	15,426	17,482	+13.3	1446	1600	+10.7

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[2] M. P. Houghton, Manager, Special Programs Branch Fisheries Service, Department of the Environment, Pacific Region.

[3] In 1970 a reorganization within the Federal Government resulted in the Department of Fisheries becoming a Service under the enlarged Department of the Environment.

costs of new vessels have been partially responsible for these higher prices for used vessels, but the increase can also be attributed to the influence of the "buy-back" program and the removal of these vessels from the market place.

The prices that fishermen are paying for salmon vessels do not reflect the increased earnings that can be realized as a result of the reduction that has taken place in the salmon fleet, but rather a value of what those purchasing the vessel think the vessel is worth.

It is of interest to examine what has happened to those fishermen who sold their vessels to the government. A summary analysis shows that as of July 19, 1972, 223 vessels had been sold to the "buy-back" plan.

— 30 of these vessels were company-owned, and no information is available on the operators.

— 46 ex-owners continued in the salmon fishery as owners of "A" category vessels.

— 6 ex-owners continued in the salmon fishery as owners of "B" category vessels.

— 6 ex-owners continued in other fisheries as owners of "C" category vessels not eligible to fish for salmon.

— 7 vessels were sold from estate of fishermen.

— 40 of the ex-owners were 60 years of age or more; they took the opportunity of selling their vessels and retiring.

— 35 of the ex-owners were between 50 and 59 years of age, and many of them are reported to have taken jobs ashore.

— Many of the other 53 ex-owners were students, but included in this group were those who found that salmon fishing was too competitive. Undoubtedly some of these 53 owners who sold to the "buy-back" did so with the firm intention of using the money received to purchase another salmon fishing vessel.

(3) *In 1970 a special salmon vessel license category with a $10 (Can.) fee was established* for native Indians who owned or *were purchasing* their own vessels.

In 1968 there were just over 1000 vessels owned or operated by Indians. About half of these were owned by fish processing companies and rented to Indians, while the rest were either owned or being purchased by Indians. Indian fishermen live for the most part in isolated communities and do not have the same opportunities for alternative employment that are available to the non-Indian.

In order to encourage Indian fishermen to continue in the fishing industry, the Federal Government had initiated a 5-year program in 1967 to upgrade vessels owned by Indian fishermen. When it became apparent in 1970 that the percentage of Indian-operated vessels was dropping at a faster rate than the total number of vessels, the Minister decided to set up a special "A" category license for Indian vessels.

Each Indian salmon vessel owner was given two alternatives: he could continue to pay the regular "A" category license fee and be eligible for "buy-back"; or he could take out a $10 (Can.) license, and as long as he continued to renew each year and fulfill the other regulations of the license program, he could renew his license indefinitely. If he opted for the special $10 (Can.) license, however, he could not sell to other than an Indian without penalty.

In 1972, 388 special Indian licenses were issued. In addition there were 23 Indians who took out full "A" licenses for their vessels.

The Indian Fishermen's Assistance Program referred to earlier has expended close to $2.5 million (Can.) in grants to between 300 and 350 Indian fishermen since 1967, and an equivalent amount in the form of loans to allow Indians to purchase better boats or upgrade their fishing equipment.

There is no doubt that this program has also had a strong influence on vessel prices since its inception, but it is impossible to separate the influences of individual factors on the increased price of salmon fishing vessels.

The Salmon Vessel License Control Program in British Columbia is still in its infancy. The final and most important phase dealing with gear and area regulations still has to be enunciated and implemented. To resolve this final phase it will be necessary to deal with the overall objectives of the Fisheries Service as they relate to all fisheries and to the economy in general. A special advisory committee of the fishing industry and other interested parties has been appointed to advise the Minister of Fisheries on this final phase, and its recommendations are expected prior to the 1973 season. The economic problems of the salmon fishery have been building up for the past 50 years and it is unreasonable to expect them to be solved in the 4-year period since the program was first introduced. The success that has been achieved in reducing the number of salmon vessels is significant at this stage of the program.

Maritime Lobster License Control Plan

As mentioned earlier the lobster limitation program was introduced in two regions of the Maritime Provinces of Canada in 1967, when an upper limit was placed on the number of operators who could participate in each region. This limit action on the number of operators was extended to all parts of the Maritimes in 1968. In 1969 regulations were changed and the maximum limit was placed on the vessel and not the operator. This change was intended to phase boats out of the lobster industry and thus reduce the number of participants.

In each of the lobster areas of the Maritimes, vessels were classified into either "A" or "B" category based on the number of traps that the boat fished in 1968. Vessels that fished fewer than the specified minimum number of traps (50–100 depending on the region) were classed as "B" category. It is the intention that these vessels would be phased out of the industry in a set period not yet defined. Boats exceeding this number were classified as "A" category and were regarded as craft that will continue in the industry.

Appeal Committees were established in each district to allow for the upgrading of "B" licenses to "A" category under certain extenuating circumstances. However, very few licenses were upgraded, and of a total of 8349 vessels licensed in 1969, 1990 were classified as "B." The percentage of "B" category vessels in the various districts as of September 1972, ranged from a low of 6.0% to a high of 52%. No further action had been taken to limit the life of "B" licenses. The maximum number of vessels that can be licensed in each region remains.

In most regions of the Maritimes no information on the number of vessels fishing lobsters is available prior to 1969. Statistics, however, are available for district 8, which includes Prince Edward Island and the part of New Brunswick bordering on Northumberland Strait. This gives an indication of possible trends since the introduction of the lobster program (Table 5).

Comparative information on the number of lobster vessels in the Maritimes is available only for 1969–70 and 1970–71, and it is significant to note that the number of vessels licensed in 1970–71 increased to 8632 from 8249 the previous year.

With restrictions on vessels now in effect it is expected that the number of vessels licensed in future years will be gradually reduced, particularly if regulations are formulated to phase out category "B" vessels.

CAMPBELL, B. A. 1972. Limited entry in the salmon fishery: The British Columbia experience. PASGAP 6.

SINCLAIR, S. 1960. License limitation — British Columbia — A method of economic fisheries management. Dep. Fish. Can. Ottawa.

TABLE 5. Number of lobster vessels and average production per vessel in district 8 of the Maritime Provinces (1965–72).

Year	No. of vessels	Production of lobsters per vessel	
		(kg)	(lb)
1964	1317	1700	3739
1965	1512	1280	2823
1966	1401	1250	2750
1967	1340	1360	3006
1968	1204	1360	3004
1969–70[a]	1204	1150	2542
1970–71	1190	1320	2887

[a]Change in licensing year.

License Limitation Regulations: The South African System[1]

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The exploitation of pelagic shoal resources off South Africa's west (Atlantic) coast began during the second world war, with large-scale expansion beginning in 1947–49. At the end of the forties, the Government lacked the scientific evidence to formulate effective conservation policies, and pending the outcome of the research programs it deemed it advisable to put a brake on the expansion of these fisheries.

An obvious measure was a ceiling on the annual catches. But this would not necessarily have prevented further influx into the fishing or the processing phases of the industry. As part of an economy-wide practice to require licenses for various kinds of operations, these were required for all fishing boats and factories. The Government decided in 1949 to refuse the issue of licenses for additional fish-processing factories and to limit the number and capacity to those already in operation or under construction.

In 1953 the fishermen, aware of the limitation on the outlets (factory intakes) for their catches, and the continued influx of outsiders into the flourishing fishing side, willingly agreed to the freezing of the number and hold capacity of vessels fishing for pilchards and maasbankers. After the enactment by parliament of the necessary enabling laws, regulations were issued to establish a Pilchard/Maasbanker Boat Limitation Committee consisting of government, factory, and fishermen representatives to apply the controls over the number of boats, their hold capacity and the allocation of this fleet to the various factories.

Adjustments, including some increases in the capacity of the fleet, were made from time to time to cope with changing conditions in the resource.

A serious weakening in the control system occurred when fishing and processing licenses were granted to operators of fishmeal factory ships.

The results of the limitation of entry into the fishing phase and the processing phases include several significant trends, among which are a smaller number of boats, larger-size boats with more powerful engines and equipment, and increased factory-ownership of boats. The factories introduced stickwater plants and other processes to increase the yield of meal from the available tonnage of raw fish.

Although the industry has experienced difficult periods, it nevertheless seems, broadly viewed, that through the policy of restricting entry at the early stages of the new industry, it acquired sufficient resilience to cope not only with the ups but also the downs. It appears doubtful that "overcrowded" fishing and processing sectors would have had sufficient resilience to face fluctuating catches and fishmeal prices.

Au large de la côte ouest de l'Afrique du Sud (Atlantique), l'exploitation des ressources pélagiques a commencé pendant la deuxième guerre mondiale et a connu une vaste expansion lors des années 1947–49. A la fin des années quarante, les pouvoirs publics manquaient de données scientifiques pour formuler des politiques de conservation efficaces, et en attendant les résultats des programmes de recherche il a paru avisé de mettre un frein à l'expansion des pêcheries.

La fixation d'un plafond aux captures annuelles semblait s'imposer. Toutefois, ceci n'aurait pas nécessairement prévenu un nouvel accroissement de l'activité des pêches ou des diverses phases de l'industrie de transformation. Dans le cadre de l'usage économique selon lequel toute opération suppose une demande de licence, on a ainsi rendu obligatoire la délivrance de telles licences pour les bateaux de pêche et pour les usines de l'industrie halieutique. Le Gouvernement a décidé, en 1949, de refuser d'octroyer de nouvelles licences pour toute usine supplémentaire de transformation du poisson et de limiter le nombre et la capacité de celles qui étaient déjà en activité ou en construction.

En 1953, les pêcheurs, conscients de la limitation des débouchés (apports de poisson à l'usine) pour leurs captures et de la pénétration constante de nouveaux-venus sur les terrains de pêche prospères, ont accepté que soient fixés le nombre et le port utile des bateaux de pêche exploitant pilchards et maasbankers. Une fois la loi nécessaire votée par le parlement, les pouvoirs publics ont institué un "Comité de limitation du nombre de bateaux exploitant pilchards et maasbankers," formé de représentants du Gouvernement, de l'industrie de

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., February, 13–23, 1973.

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transformation et des pêcheurs et chargé d'appliquer les règlements visant le nombre des bateaux, leur port utile et la répartition de cette flottille entre les diverses entreprises de transformation.

On a procédé à quelques ajustements, notamment en accroissant le port utile des bateaux, pour faire face à l'évolution des conditions concernant les ressources. Le système de contrôle a été gravement affaibli lorsque l'on a accordé des licences de pêche et de transformation aux exploitants de bateaux-usines fabriquant de la farine de poisson.

Les limitations imposées à l'accès à la pêche et au traitement du poisson ont donnée lieu à plusieurs tendances significatives, parmi lesquelles une réduction du nombre de bateaux, la mise en service d'unités de plus grande taille dotés d'engins et d'équipements plus puissants et une extension de l'armement par les entreprises de transformation. Celles ci ont mis en service des usines pour le traitement des déchets gélatineux et pour l'exploitation d'autres brevets, afin d'accroître le rendement en farine à partir des tonnages de poisson disponibles.

Bien que la pêche ait connu des périodes difficiles, il semble néanmoins que grâce à la politique limitant l'accès aux stades initiaux de la nouvelle industrie, celle-ci ait acquis suffisamment d'élasticité pour faire face à ses vicissitudes. Il paraît douteux que les secteurs de la pêche et du traitement du poisson, s'ils avaient été trop chargés, eussent pu faire face aux fluctuations des captures et des prix de la farine de poisson.

La explotación de los recursos pelágicos que viven en cardúmenes frente a la costa occidental de Sudáfrica (Atlántico) comenzó durante la segunda guerra mundial y experimentó una rapidísima expansión a partir de 1947–49. A finales del decenio de los años cuarenta, el Gobierno no disponía de datos científicos suficientes para formular medidas eficaces de conservación y, en espera de disponer del resultado de los programas de investigación, consideró oportuno frenar la expansión de estas pesquerías.

Una medida obvia era establecer un máximo anual de captura, pero era imposible saber con certeza si esa medida limitaría la entrada de nuevas embarcaciones a la pesquería y el aumento del número de empresas elaboradoras. Dado que como parte de un sistema económico general que exigía solicitar licencias para varios tipos de actividades, se requerían licencias para las embarcaciones y las fábricas pesqueras, en 1949 el Gobierno decidió rehusar la concesión de nuevas licencias para fábricas de elaboración de pescado y limitar el número y capacidad de las que ya funcionaban o estaban en construcción.

En 1953, los pescadores, conscientes de la limitación de las salidas (insumos de las fábricas) para sus capturas y la continua entrada de extraños en esta pesquería floreciente, acordaron de buen grado congelar el número y capacidad de bodega de las embarcaciones dedicadas a la pesca de sardina y "maasbanker". Tras la promulgación por parte del Parlamento de las leyes correspondientes, se publicó una orden en virtud de la cual se creaba un Comité para la limitación del número de embarcaciones dedicadas a la pesca de sardina y "massbanker," compuesto por representantes del Gobierno, de las fábricas y de los pescadores, que se encargaría de controlar el número de embarcaciones, la capacidad de bodega de las mismas y la distribución de la flota entre las diversas fábricas.

De tiempo en tiempo se introdujeron reajustes, incluido cierto aumento de la capacidad de la flota, para adecuarse a las variaciones que se iban produciendo en la situación de los recursos.

Cuando se concedieron licencias de pesca y elaboración a los armadores de buques-factoría dedicados a la fabricación de harina de pescado se produjo un grave debilitamiento del sistema de control.

Entre los resultados de la limitación del acceso a la pesquería y al sector elaborador figuran varios logros importantes, entre ellos la reducción del número de embarcaciones, el aumento de las dimensiones de las embarcaciones y la mejora de los motores y el equipo, y el incremento del número de embarcaciones de propiedad de las fábricas. Estas últimas introdujeron plantas de agua de cola y otros sistemas para incrementar el rendimiento en harina del pescado disponible.

Aunque la industria ha atravesado períodos difíciles, parece, en general, que, gracias a la política de limitar el acceso en las fases iniciales, la industria ha adquirido suficiente elasticidad para aguantar todos los altibajos. Es dudoso, en cambio, que un sector pesquero y elaborador "saturados" hubieran tenido suficiente elasticidad para afrontar las fluctuaciones de las capturas y de los precios de la harina de pescado.

THIS paper describes the licensing policies adopted by the South African State authorities as part of a conservationist management program to ensure restriction of entry into the primary and secondary phases of the West Coast shoal fisheries based on six pelagic species. It does not deal with conservation and management measures such as closed seasons, closed areas or sanctuaries, minimum mesh sizes for nets, minimum sizes for fish species, etc. However, many of these measures are closely linked with the provisions restricting entry into the industry. The West Coast shoal fisheries constitute the largest sector of the South African fisheries in terms of volume.

The shoal fisheries were virtually nonexistent before the outbreak of the second world war. As a result of the wartime demand for canned fishery products they emerged, but only to an insignificant level, during the years 1942–46. A noticeable increase of catches took place in 1948 and the upward trend continued to 1963, with occasional fluctuations in the level of annual catch of the three main species (maasbanker, pilchard, and chub mackerel). In 1964 the Cape anchovy and the round herring entered the picture, and lanternfish appeared in the catches for the first time in 1970.

During the initial phase of the large-scale expansion of these pelagic fisheries in the late forties and early fifties, the soaring earnings of the fishermen and the booming profits of the fish processors naturally attracted many newcomers to fishing and fish processing. This flood of entrants soon gave rise to concern in Government circles. At about this time, the California sardine fishery experienced a complete collapse, which according to some scientists was caused by overfishing. This specter increased South African fears of overfishing the recently developed West Coast pelagic resources.

At this critical stage the Government lacked the scientific evidence about these resources that was needed to formulate guidelines and conservation policies. The existence of these resources had for many years been known to Government scientists, but private enterprise had hitherto been hesitant to risk investments in their exploitation. As a result, fishery research until the forties had been chiefly concerned with the other resources (Cape hake, Agulhas sole, rock lobster, etc.), that had been exploited since the turn of the century.

In these circumstances, the Government had to take without delay some precautionary measures pending the outcome of research programs on the West Coast pelagic species. It seemed advisable at this stage to put a brake, at least temporarily, on the growth of the industry fishing and processing these species.

The most obvious course of action appeared to be to put a ceiling on the quantities of these species caught annually or seasonally. However, there was no legislation that gave authority for annual or seasonal quotas limiting the catch. On the other hand, quotas would not necessarily discourage overoptimistic would-be fishermen or processors. Furthermore, should the research programs produce evidence indicating the need for drastic reductions in the overall catches, the Government would have to face demands from the entire fishing and fish processing community to bail them out of the difficulties caused by their overinvestment of labor, capital, and management in a declining or reduced sector of the national economy.

The available fisheries legislation required annual licenses, granted for very nominal fees, from all owners of fishing boats and fish processing factories. The Government thus turned to its existing powers to issue or to refuse to issue licenses to would-be entrants.

Many South African parliamentary legislative acts and provincial ordinances required annual licenses (issued largely for revenue and/or registration purposes) from owners of vehicles, factory or shop premises, etc., and for undertaking various commercial, industrial, and occupational activites. However, in establishing such licensing powers it was not envisaged that they would be used to restrict entry of entrepreneurs into the various sectors of the economy.

In 1940 the South African Parliament enacted the *Sea Fisheries Act, Act No. 10 of 1940* which transferred to the Central Government responsibility for marine fisheries from the two Provincial Administrations of the Cape of Good Hope and of Natal — the two maritime provinces. This act provided (as was formerly required by the now repealed Cape and Natal fisheries ordinances) for the licensing of boats and fish processing premises. These provisions read as follows:

Article 5: (1) No person shall use any unlicensed vessel as a fishing boat or as a factory, or use any unlicensed premises as factory.

The Sea Fisheries Act and subsequent amending acts also made it clear that its various provisions (as enacted or promulgated in the Government proclamations or notices issued administratively under its delegated powers) applied to vessels, fishermen, equipment, etc., even beyond the country's territorial waters, provided that such vessels were required to be licensed under the terms of the *Sea Fisheries Act*.

Limitation of the Number and Capacity of Reduction Plants in South Africa, 1949–64

NATURE AND SCOPE OF THE CONTROLS

The fears about overfishing the South African pilchard stocks which manifested themselves in official circles in the late forties resulted in several amendments to the *Sea Fisheries Act, 1940* by the South African Parliament. The 1949 and 1953 amending acts introduced a new subsection which empowers the Government, on recommendation of the Fisheries Advisory Council, to issue, amend, or rescind "proclamations" which could determine the following: a) fix the maximum quantities *of fish* of any *one or more* species of fish that, in 1 year, may be treated in any one factory; b) limit generally or in any defined area the number and capacity of plants that may be used for the *canning of fish* or for the manufacture of fishmeal, fish oil, *or fish fertilizer;* c) prohibit any person from using in any *defined* area any vessel for manufacturing fishmeal, fish oil, *or fish fertilizer* or for the freezing of rock lobster tails or for the canning of fish; d) *fix the maximum quantities of canned fish, fishmeal, fish oil, or fish fertilizer that, in any one year, may be produced by any one factory.*

The words not in italics were introduced by the 1949 amendment and the italicized ones were added by a further 1953 amending act.

By these powers granted to the Government in 1949 it was possible to limit the number and capacity of the plants producing fish oils and meals. The 1953 additions extended these restrictive powers to plants producing fertilizers, and to canneries.

These far-reaching powers, delegated to the State agencies by the South African legislature, enabled the latter to refuse "entry" to would-be processors either generally or in a particular area; the raw materials (as to species and quantities) used by any existing plant could be prescribed; the output of any particular factory could be limited. Not all of these powers to control and restrict the processing industry have been used, but proclamations limiting the number and capacity of reduction plants using pilchards and maasbankers, and the number of canneries utilizing these species have been issued. They are intended to prevent the industry from expanding and thereby, through an increased demand for fish, encouraging an expansion of landings of "raw" fish to levels which would result in overfishing.

The first proclamation issued in terms of the 1949 amendment limited the number and capacity of reduction plants to those in actual existence on October 27, 1950. Further amending proclamations followed in quick succession to extend this limitation to more magisterial districts than were originally listed in the first proclamation, in order to forestall attempts to evade the restrictions by erecting plants even in inland districts. Others added the proviso that plants for which firm orders had been given and accepted were also included.

Toward the middle of 1953 all authorized plants had been erected and were in operation, and the currently valid proclamations now limit the pilchard and maasbanker reduction industry in the Cape Province of South Africa as follows: to the number of plants in existence on August 28, 1953 and on this date actually used for the manufacture of fishmeal, fish oils, or fish fertilizers from pilchards and maasbankers; to the capacity of each plant as on August 28, 1953. Establishment of additional plants are subject to approval by the State President. Since 1953 the number of plants has been increased on only two occasions. In 1959 the maximum quantity of pilchards and maasbankers that could be processed annually in the factory of Gansbaai Cooperative Fisheries was fixed at 15,000 short tons. Late in 1960, a fish cannery which had not had a reduction licence for several years was granted one for a 5-ton intake capacity; this could, of course, be transferred for use by an adjacent existing reduction factory to permit the expansion of the latter to process inter alia the offal from the cannery.

PROBABLE EFFECTS

The restriction since 1950 on new entrants to the reduction industry immediately placed a very high value on the ownership of a license to install and operate a fishmeal factory, and became the very foundation of all flotations of public or private companies venturing into the booming inshore fishing industry of the West Coast during the early fifties.

Approximately a dozen licenses were issued and factories were established at several fishing centers along the West Coast. In two instances the old sites were abandoned and the licenses were transferred to new factories constructed at more convenient locations. Mergers and combinations among the various parent companies and their subsidiaries have eventually resulted in the ownership of these valuable licenses becoming lodged in the hands of a few large company groups.

Every license issued also specifies the maximum intake capacity of the reduction unit(s) that the owner is allowed to install and to operate. In certain instances companies have combined any unused balances and have applied them to cover the installation of further plants by joint subsidiaries.

Considering the South African reduction industry as a whole, it would seem that the intake capacity of 240 short tons (per hour) of raw fish on approximately a 20 days per month basis for the first 7 or 8 months of the year would absorb between 850,000 and 900,000 short tons. However, it is doubtful if this volume could actually be achieved. The factories are located at several harbor centers spread over a long coastline along the Atlantic seaboard of the Cape. Annual and seasonal variations in the regional abundance of the fishable stocks would undoubtedly result in great differences in the degree of utilization of intake capacity from factory to factory. Further distortions in the capacity pattern of the industry are no doubt caused by the policies of municipalities and local councils of residential areas near newly located fishing grounds. Refusal to grant sites for factories close to the new grounds can increase the degree of underutilization of the licensed and installed capacities of plants whose locations have become unfavorable. This factor must, however, be considered against the social costs of destroying or otherwise adversely affecting the residential amenities of attractive coastal zones.

The South African Board of Trade and Industries, in a report issued early in 1953 on an investigation of the fish processing industry, commented on the "very large measure of trustification" which already existed in this branch of the national economy. It stressed the monopoly effects that arise from the methods of control, to achieve conservation objectives, already imposed by the South African Government: "Conservation measures may bring about, or assist in bringing about, monopolistic market structures. Measures such as those taken in 1950 could have various restrictive effects. First, by limiting the entry of new firms as well as the capacity of existing establishments, they directly restrict output. Secondly, by limiting entry they might encourage the growth of an *esprit de corps* among those privileged to be in the market, causing them to exchange shares in subsidiary firms operating at different places or jointly to participate in the establishment of new undertakings in regions still in the course of development... Thirdly, they are bound to have a monopolistic effect in the sphere of income distribution, permitting as they do only those already in the industry to share in the earnings to be made."

During the fifties the processing firms enjoyed an expanding world market for their products. Faced with the various state-imposed restrictions (on the capacity of the processing plants, on number and tonnage of the fishing fleet, etc.) affecting their intake of fish, the factory managements began to install stickwater plants to increase and raise the quality of output from a limited available quantity of raw fish. It appears that this trend toward a more intensive utilization of the raw materials has been accelerated by the restrictions imposed under the conservation policies adopted by the state authorities.

In the internal South African fishmeal market the prices were controlled at levels significantly below those prevailing on the world markets. This control was applied as part of a general control over the costs and prices of animal feeds. The "privileged" firms already in the reduction industry were thus required to meet the total domestic demand at this lower price before exporting surpluses to overseas markets. This encouraged the fishmeal producers to market their output through their trade association in a one-channel disposition system. This assured an equitable distribution of (a) the burden of the lower-priced domestic market and (b) the reward of the higher profits from export sales.

Elimination of any of the existing restrictions on the issue of factory licenses would not necessarily reduce monopolistic trends, since new license holders would likely use the now existing "one-channel" marketing structure. Additional licenses would also require an increase in the number and tonnage of the fleet, which is now restricted by the boat limitation policy. None of the existing firms could be expected to reduce their fleet allocation (in terms of number and tonnage) for the benefit of newcomers.

Limitation of the Number of Canneries in South Africa, 1953–64

NATURE AND SCOPE OF THE CONTROLS

The first amending act, that of 1949, did not include fish canneries and referred only to reduction plants. The 1953 amendment enabled the state agencies to control and restrict the number and the intake and output of fish canneries located in the Cape Province. In December 1953 the Government issued a proclamation limiting the number and capacity of pilchard/maasbanker canning plants to those in existence on December 11, 1953 and actually used for this purpose on that date. This measure also provided for additional canneries subject to the approval of the State President.

In June 1954, the 1953 proclamation was amended, and all references to the capacity of canning plants were deleted; the restrictions now only apply to the number of canning plants.

PROBABLE EFFECTS

From a conservation point of view there appears little justification for limiting the number of canning plants while leaving unrestricted the intake capacity for the existing plants of firms already privileged to be in the industry. In its report prepared in 1952–53 the Board of Trade and Industries commented on this matter: "As for the second question posed above, it is doubtful whether, in an industry of this nature, the present methods of output control are efficient. First, the control is not sufficiently comprehensive. If it is at all necessary, it should be extended to include the canneries. In a pilchard conservation program every significant user of fish should be controlled. More important still, it is difficult to prevent a cannery from developing into a cannery-cum-reduction plant, or even a reduction-plant-cum-cannery. In the pilchard industry, specialization is wasteful. On the average, apparently, only a relatively small proportion of fish taken can be canned. In addition, the fish offal goes to waste. Consequently, particularly in times of keen competition, a specialized cannery must find it difficult to compete with a firm combining a cannery with a reduction plant. Hence, there is a strong tendency towards combining the two activities; and when a cannery applies for a license to establish a reduction plant, the authorities, anxious to see that the best use is made of the fish taken, find it difficult to refuse. At present persons wishing to erect canneries are warned that they will not be granted a license for a reduction plant as long as the existing restrictions are maintained; but this is obviously not a satisfactory way of dealing with the matter. For the time being, it would seem, no independent new canneries should be established; but there could be no objections to an extension of canneries attached to already existing reduction plants, provided the intention were to can a larger proportion of the fish which would in any case be taken."

Control Over the South African Pilchard/Maasbanker Fishing Fleet, 1953–64

NATURE AND SCOPE OF THE CONTROLS

In 1953 fishermen and factory managements indicated to the Government their desire to cooperate in the field of conservation by accepting an annual quota of 250,000 short tons of fish. This limitation, and the restriction on the erection of reduction plants, made the fishermen and fishing boat owners aware of the shrinking opportunities for catching fish and finding outlets for their catches. At the same time the professional fisherman of long standing became aware that many of the new entrants were teachers, doctors, etc., who were attracted by the boom conditions and had acquired boats. The professional fishermen, therefore, willingly agreed to freeze the strength of the fleet fishing for pilchards and massbankers.

As part of the general agreement reached in 1953 between the Government and representatives of the fishermen and factory managements, it was decided to peg the strength of the fishing fleet used along the West Coast for the catching of pilchards, maasbankers, and mackerel at the number of boats then in commission, together with those under construction and those for which firm orders had been placed and accepted by January 31, 1953. This agreement was closely related to the establishment of a 250,000 ton annual quota and the limitation of the number and capacity of the processing plants.

It was necessary to strengthen this agreement by legal measures. Accordingly, the Sea Fisheries Act 1940 was amended by Parliament to introduce a new subsection 1 *bis* under terms of which "regulations . . . may provide for the issue of a license in respect of a fishing boat subject to the condition that such a boat is not to be used for the catching of fish of any species specified in the license or of fish other than fish of a species so specified." The same new subsection added the proviso that such a condition is to be imposed only after consideration of the matter by a committee constituted in a way prescribed in the regulations.

This new enabling clause was administratively extended in detail in July 1954 and on subsequent occasions. The new regulations established a *Pilchard/Maasbanker Boat Limitation Committee* consisting of the Director of Fisheries as chairman, four members (with four alternates) to represent the pilchard/maasbanker fishermen, and four other members (with four alternates) to represent the factories processing these species. Six members form a quorum and all questions can be settled finally by a majority of votes present.

The owner of a boat which is to be used for catching pilchards and maasbankers applies to this Committee, whose chairman then issues a "pilchard/maasbanker boat licensing certificate" on which is stated whether or not the application to fish for these two species has been approved by the Committee. This certificate, together with the application for the fishing boat license, is then handed to the Internal Revenue Department, who issues, on payment of the annual license fee for that type of boat, the license endorsed as to whether the boat is authorized to fish for pilchards and maasbankers. If not endorsed with authorization to participate in this fishery, the boat owner is entitled to use his boat for catching all the other species.

Two types of licenses for the pilchard and maasbanker fishery are issued. The "unrestricted" type enables the boat owner to fish for these species and to have his catches used in any form of processing, including canning and reduction. With the "restricted" license, issued only to a few boats, the catches cannot be delivered to canneries and reduction plants but must be used for limited purposes such as bait, salting, drying, and smoking, and for the delivery to dealers in the fresh fish disposition channels that are able to absorb only very limited quantities of these West Coast pelagic species.

These restrictive measures, limiting entry into a comparatively profitable economic activity, immediately invested the boat owning parties already "in" with economic and legal rights. These licenses acquired a significant financial value, and today it is important from a legal point of view to determine in the sale of any "pilchard" boat whether or not it is sold as a craft with or without the rights to a capacity tonnage (hold) for use in the shoal fishery.

Under this system, entailing license endorsements, a fisherman who desires to replace his old boat having a hold capacity of say 55 tons with a larger one with a capacity of say 130 tons is required to surrender his licence for the 55-ton boat together with enough licenses for other boats to cover the balance of 75 tons. These smaller boats, unless sold to new owners holding pilchard/maasbanker fishing licenses, must be withdrawn from the West Coast shoal fisheries as soon as the new boat comes into operation.

This system of control required the establishment of a boat register for the fleet participating in the pilchard and maasbanker fishery. This is reviewed regularly by the Boat Limitation Committee.

In 1957 a further agreement between the representatives of the fishermen and the factory managements was reached and the Boat Limitation Committee established individual "boat registers" for each processing factory in June 1957. All boats on the overall fleet register were allocated to these factory registers. The total hold capacity of the boats permitted to make deliveries to a particular factory was pegged at the aggregate capacity of the boats appearing on the factory register plus 20%. This increased aggregate could not be exceeded by the individual factory fleet in future years. In the case of one or two factories which were experiencing a boat shortage, a few additional boats were allowed before their tonnage ceilings were calculated.

The number of craft on each factory register was also pegged to that on the registers in 1957. Exceptions to this rule were made in the case of two factories located on the Berg River estuary, which required the use of small boats to cross the sand bar at that river mouth. Their fleets were not restricted in numbers but the ceilings of their aggregate fleet tonnage (hold capacity) could not be exceeded.

These new restrictions add tremendously to the work of the Boat Limitation Committee. Every time a boat changes ownership or is withdrawn from the fishery or a new one is introduced, the Committee has to consider all the implications in terms of the overall register and of the various factory subregisters.

Before the 1957 agreement came into operation an owner could introduce a boat with an increased hold capacity by withdrawing a number of smaller craft or, for example, by acquiring and handing in the license of a vessel that had been shipwrecked. With the introduction of factory registers and a ceiling on the number and total tonnage of the craft making deliveries to any particular factory, adjustments also have to take these factory aspects into account. For example, a fisherman might own two boats of 50 and 40 tons, on the registers of two separate factories. He may wish to withdraw both boats and replace them with a 90-ton vessel to fish for one factory. This would only be possible if that particular factory has the necessary unused capacity available. If the fish move away from the grounds near a factory, the fishermen registered there might find fishing unprofitable and wish to make deliveries to a factory nearer to the new fishing grounds. However, such a transfer would not be approved if the more conveniently located factory had a full register. It could also happen that even if the fisherman could move to another factory he may find himself prevented from returning should the fish shoals go back to the old fishing grounds; the original factory might in the meantime have acquired boats utilizing all the available tonnage on its register.

PROBABLE EFFECTS

The implementation of the boat limitation scheme after 1954 accelerated, even if it did not actually cause, certain trends in the structure and nature of fishing activities. These trends were reflected in the ownership pattern within the fleet and changes in size of the individual craft, which in turn were partly responsible for certain developments which have had a significant impact on costs and earnings pattern of the fleet.

Boat earnings declined on the average during the years 1955–57 as a result of the drop in the availability of fishable stocks. The fall in world fishmeal prices following the expansion of the Peruvian anchoveta fishery and processing industry also resulted in lowered prices per ton for raw fish delivered to South African factories in 1960. Meanwhile costs have risen, and the southward movement of the shoals away from the northern factories has increased the operating radius and fuel bills. Thus, since the fifties, a need for larger and more economical boats began to be felt.

Originally most of the boats were owned by private fishermen. Factory managements were not eager to increase the number of factory owned craft since the ownership interest of the fishermen was considered sound. In 1956, when the catches dropped to a very low level (134,389 short tons), fishermen began to sell their boats to factories. The latter had to acquire these boats because their sale at that time to other factories would have resulted in loss of local fishing potential which was at a premium because of the boat limitation policy. Moreover, during a period of reduced abundance the use of every possible boat was important to meet the intake capacity of each factory.

When the southward movement of the shoals led to a demand for larger, more expensive boats, these in most cases could only be financed by the factories and by the more successful fishermen-owners. But the large boats could not be ordered without surrendering the specially endorsed licenses of two or more smaller boats.

These trends stimulated increased efficiency of operation. Fishermen began using echosounders, power blocks, and bigger nets. The need to travel longer distances to the fishing grounds and to convey catches more rapidly to shore-based factories encouraged the introduction of bigger boats with increased engine power. The power blocks also enabled the size of the boats to be significantly increased without corresponding increases in crews and in the number of persons sharing the available "fishing cake."

In some quarters it is considered that this process was not rapid enough, and that the protection given to fishermen by the restrictive license policy reduced the incentives to introduce innovations and to experiment with technoligically improved gear. It is difficult to judge whether these improvements would have taken place more rapidly had there been no restrictions on licenses.

The improvements in size and technical equipment of boats was accomplished without any form of Government subsidy, the capital needed for the improvement of the fleet being provided by the factories or by private fishermen. The fishermen, however, had access to loans for boats provided by the Fisheries Development Corporation of South Africa, and they benefited by being sheltered from the competition which would have resulted through an uncontrolled influx of fishermen and boats into the primary industry.

Of a total fleet of 217 boats in July 1955 with an aggregate tonnage of 7700 tons, the factories owned only 79 (2884 tons) compared to 138 (4821 tons) belonging to nonfactory owners. At this time the average capacity of these two groups of boats was about the same (37 tons for factory boats and 35 for boats in other hands). Two years later (July 1957) the position had changed: the factories owned 98 of a total of 182 boats. This trend continued, and in February 1960, 106 factory-owned boats accounted for a total tonnage of 6911 tons, compared to 46 boats otherwise owned with a total of 2564 tons. The factory boats had on the average a hold capacity of 65 tons compared to 56 tons for the others. There has been a steady drop (from nearly 230 to 150) in the number of boats permitted to fish "unrestrictedly" for pilchards and maasbankers since the introduction of the boat limitation scheme in 1953. The fleet varied between 7700 and 8500-ton capacity until after 1957 when the agreement of that year enabled the factories to increase the tonnage of their individual fleets by 20%, without increasing the number of craft. The rapid increase (almost a doubling over a period of 5–6 years) in the average size of boats (in particular those owned by factories) is also reflected in these figures.

By February 1960 the number of boats with unrestricted licenses for pilchard/maasbanker fishing had dropped to 152, with a total fleet hold capacity of nearly 9500 short tons, an average of 62 tons per boat. By July 31, 1962 the number was down to 122 boats with 9800 short tons hold capacity, which reflects an increase in the average per boat to 81 short tons. New licenses to fish for pilchards and maasbankers were granted to boats based on Gansbaai, where a reduction plant was opened. This increased the fleet capacity to 11,400 short tons by June 1, 1964. The number of boats remained stable but the replacement of smaller boats is indicated by the average size rising to 91 short tons.

The craft permitted to fish under "restricted" licenses are few, and their average size remains small compared with those permitted to deliver catches to reduction factories and canneries.

Although accurate figures showing the manpower aboard the restricted license boats are not available, it is obvious that their numbers must have decreased significantly. The larger boats on the average require only one or two men more than the complement required for the smaller ones; for example, a 55-ft boat is manned by 9 and a 69-ft by 11 men. In 1954 some 1800–1900 men must have been employed, compared with 1500–1600 in 1960.

Developments in the Licensing System, 1965–71

INCREASES IN THE PROCESSING CAPACITY OF THE SHORE PLANTS

After pegging the number and capacity of the reduction and canning plants in 1953, the Government for 12 years maintained its policy of not issuing additional licenses and not authorizing increases in the capacity of individual plants, except for one or two minor expansions. The most important of these was the establishment in 1963 of a reduction plant at the harbor of Gansbaai. This harbor is situated on the south cost and it provided an outlet for shoal fish catches taken in the waters to the east of the Cape of Good Hope. To operate a 20-ton reduction plant the factory obtained a 15-ton license from the Government, to which it added 5 tons of an existing license issued to the factory on the west coast and not used there. An additional number of boats to provide catches for this reduction plant was also authorized, as mentioned earlier.

In 1965 further concessions were made. The raw fish capacity in December 1960 amounted to 247 short tons, and this was increased in 1963 by the 15 tons for the Gansbaai factory, which brought the total to 262 short tons of raw fish per hour. The 1965 concessions increased this capacity by almost 20%, to 314 short tons per hour. This was accompanied by a similar expansion of the fishing fleet's hold capacity. It would appear that this 1965 increase was considered to be justified by the Government on the grounds that a new resource had been added to the west coast shoal fisheries — the Cape anchovy. In 1964 the Fisheries Development Corporation provided funds for experimental fishing for anchovies by several boats. This proved successful, and the catches of Cape anchovy amounted to 95,400 metric tons in 1964 and 178,300 metric tons in 1965.

The 1965 increase in the fleet by 20% was granted in respect of the hold capacity and not in number of boats. This further encouraged the introduction of larger boats but it did not result in an appreciable increase in the number of fishermen, since the crew size remained about 9–11 men per boat. This hold capacity increase benefited shore factories since it eased the situation somewhat by providing additional fleet capacity per factory. It is felt that the tying of specified number of boats to individual factories results in uneven distributions of the boats. A factory's fleet capacity does not necessarily relate to the processing capacity of the shore-based plant and to the availability of fish in nearby waters. By increasing the hold capacity of a factory's fleet of boats some additional flexibility has been gained.

LICENSING AND THE INTRODUCTION OF FISH FACTORY SHIPS

In 1965 several companies operating shore-based factories acquired now surplus whale factory ships belonging to European countries withdrawing from Antarctic pelagic whaling. Two of these ships were converted to floating fishmeal factories. The Government issued two licenses (although there were reports that many more applications for licenses to operate such vessels were submitted), to the *Willem Barendsz* (a former Dutch whaling ship) and the *Suiderkruis* (which had operated previously as the Norwegian whale factory ship *Kosmos V*). The licenses required the operators to use only fish caught outside the 12-mile limit (6 miles territorial waters plus 6 miles contiguous fishery zone). The first converted fishmeal factory ship began operation in July 1967 with 18 catchers.

In 1970 the Government, under pressure from shore-based fishermen and plants, requested the factory ships to move and in that year they began to operate off the west coast of North Africa. The *Willem Barendsz* returned to the Southeast Atlantic in 1971. One ship has now been withdrawn from activity while the other, with a new name and under a new flag has continued to operate off the west coast of North Africa.

In some quarters it is argued that it was an unwise step to grant licenses to these two factory ships and their fleets of catching boats. It was felt that the established policy of keeping brakes on the catching and processing sides of the industry, pending scientific establishment of the extent of the resources and the annual yield that could be harvested, was seriously undermined or almost cast aside.

It would seem that once a government has (through entry restrictions, seasons, quotas, etc.) placed a limit on the expansion of a common property resource industry, it should not remove these in any way unless there is irrefutable evidence in favor of the lifting of restrictions. It is very difficult to restore the old levels once these have been exceeded by new entrants — either in the form of boat operators or of fish processors.

License Limitation Regulations: The Japanese System[1]

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ASADA, Y. 1973. License limitation regulations: the Japanese system. J. Fish. Res. Board Can. 30: 2085–2095.

Fishery regulations in Japan derive from the "Old Fisheries Law" of 1901. This law recognized and legalized traditional institutions and practices. In 1949 a new law replaced the "Old Fisheries Law" and this in turn was amended substantially in 1962.

From the legal viewpoint fisheries are divided into three categories, "Fishing Rights Fisheries," "License Fisheries," and "Other Fisheries." License Fisheries produce 60% of catches and this proportion has gradually increased over many years. Coastal Fisheries are controlled by the Fishing Rights system. "Common Fishing Rights" are those that enable fishermen to exploit a certain area of water in order to harvest shellfish and seaweeds and to operate small types of fixed gear and small mobile gears such as beach seines set from nonmotorized craft. "Set Net Fishing Rights" are granted for gears fixed in water shallower than 27 m. "Demarcated Fishing Rights" enable holders to engage in fish culture within a given coastal area. Fishing Rights are monopolistic rights to engage in certain fisheries in certain areas of public waters. They are thus property rights, and in legal transactions most of the same provisions concerning land apply to them.

The major fisheries are controlled by licenses. A fishing license legally exempts an individual from general prohibitions declared for the purpose of conservation or the maintenance of order in the exploitation of fishing grounds. There are two categories, licenses granted by the Minister of Agriculture and Forestry, and licenses granted by Prefectural Governors. The former licenses are required to engage in fisheries for which national control is considered necessary because of the large size of the vessels engaged, the wide area of fishing operation, the existence of international fishery agreements, and the nature of the fishing grounds, etc. Seventeen fisheries come under these licenses. Prefectural Governors issue licenses to vessels engaged in fisheries next in importance to the above group. The number of vessels to be licensed in each fishery is determined in consultation with Fisheries Coordination Committees by size-class of vessels, fishing area, and periods of operation. Licenses are subject to restrictions in respect to areas fished, closed seasons, vessel tonnage, equipment and power, minimum size of fish caught, and other things.

All Japanese fisheries are controlled as a unit. Almost all are limited in the number of vessels that may take part. In recent years there have been few fisheries where the number of licenses issued has increased, but there has been a rise in the size of vessels and the quality of their equipment. Since fishing effort is controlled by the limitation on the number of licenses, in several instances their number has been reduced when exploitation seemed too high. In some cases vessels have been transferred to other fisheries; in others those forced out have been compensated by those remaining. But since renewal is nearly assured the license acquires value, and investments and loans are made taking the license as security. There is no fee charged for the licenses. It would have been better if one were, and the income used to compensate those who are forced out.

A "tonnage supplement system" is used to reduce the effects of increase in fishing power resulting from the use of larger and more efficient vessels within the licensing system. To replace a vessel with another of larger size, the equivalent extra tonnage must be retired by purchase of a license or some other means.

The system used in Japan arose in response to conditions in that country, and is regarded as successful. Other countries considering license limitations should consider their special problems to judge whether such a system is appropriate.

Les règlements sur les pêches qui sont en vigueur au Japon proviennent de la vieille législation sur les pêches de 1901. Cette législation reconnaissait et légalisait des institutions et des pratiques traditionnelles. En 1949, la vieille législation était remplacée par une nouvelle, qui fut amendée substantiellement en 1962.

Du point de vue juridique, on a subdivisé les pêcheries en trois catégories: celles dépendant des droits de pêche, celles autorisées par une licence de pêche et les autres. Les pêcheries de la deuxième catégorie réalisent 60% des captures et cette proportion a progressivement augmenté depuis de nombreuses années.

Les pêcheries côtières sont assujetties au système des droits de pêche. Les "droits de pêche communs" permettent aux pêcheurs d'exploiter certaines zones aquatiques afin d'y récolter les mollusques et crustacés et les algues en utilisant des engins fixes de petite dimension et de petits engins mobiles, tels que les sennes de

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., February 13–23, 1973.

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rivage mises à l'eau par des bateaux non motorisés. Les "droits de pêche au filet fixe" autorisent la pêche au moyen d'engins fixés dans les eaux d'une profondeur inférieure à 27 m. Les "droits de pêche cantonnés" permettent à leur titulaire d'exercer la pisciculture dans une zone côtière donnée. Ces droits de pêche confèrent le monopole de pratiquer une certaine pêche dans certaines zones du domaine public. Il s'agit donc de droits de propriété, et la plupart des dispositions concernant les biens terrestres leur sont applicables dans les transactions juridiques.

Les grandes pêcheries sont placées sous le régime des licences de pêche. Du point de vue juridique, une licence exempte une personne des interdictions générales prescrites afin d'assurer la conservation des ressources biologiques ou de veiller à l'exploitation des terrains de pêche. Il existe deux types de licences, celles qui sont accordées par le Ministre de l'agriculture et des forêts et celles qui sont délivrées par les préfets. Les premières sont indispensables pour participer aux opérations de pêche sur lesquelles un contrôle national est jugé nécessaire étant donné les grandes dimensions des navires participants, la vaste superficie de la zone d'opération, l'existence d'accords internationaux, la nature des terrains de pêche, etc. Dix-sept pêcheries sont assujetties à ce système de licences. Les préfets délivrent d'autres licenses aux bateaux qui participent aux pêches de moindre importance. Le nombre des bateaux autorisés dans chaque pêcherie est déterminé en consultation avec le Comité de coordination des pêches par classe de bateaux, zone de pêche et période d'opération. Les licences sont délivrées sous réserve de restrictions portant sur les zones d'exploitation, les saisons de fermeture, le tonnage des bateaux, leur équipement et leur puissance, la taille minimale du poisson capturé, etc.

Toutes les pêcheries japonaises sont soumises à un système de contrôle qui leur est propre. Dans chacune d'elle le nombre des bateaux admis à participer à la pêche est limité. Lors des dernières années, le nombre des licences délivrées n'a augmenté que dans quelques pêcheries, mais les dimensions des bateaux se sont accrues et la qualité de leur équipement s'est améliorée. Puisque l'effort de pêche est contrôlé par la limitation du nombre de licences accordées, dans plusieurs cas où le taux d'exploitation paraissait trop élevé on a réduit ce nombre. Il est arrivé que certains bateaux soient transférés dans d'autres pêcheries; parfois ce transfert a donné lieu à une compensation au profit des navires restants. Etant donné que le renouvellement des licences est presque assuré, ces dernières ont pris de la valeur et servi de garantie à des investissements et à des prêts. Aucune redevance n'est perçue lors de la délivrance des licences. Il faut le regretter, car les fonds ainsi recueillis serviraient à compenser les exploitants qui sont exclus de la pêche.

On a recours à un système de "supplément de tonnage" pour atténuer les effets de l'augmentation du pouvoir de pêche résultant de l'utilisation de bateaux plus grands et plus efficaces dans le cadre de la délivrance des licences. Pour remplacer un navire par un autre de plus grande taille, on doit se procurer une licence ou recourir à quelque autre moyen de compenser le supplément de tonnage résultant de l'opération.

Le système utilisé au Japon s'est constitué pour répondre aux conditions qui règnent dans ce pays et on estime qu'il a donné des résultats satisfaisants. Les autres pays qui envisagent de limiter la pêche par la délivrance de licences devraient examiner leurs problèmes particuliers pour décider si un tel système est approprié.

La regulación del sector pesquero en el Japón comienza con la "Antigua Ley de Pesca" de 1901, que reconocía y legalizaba las instituciones y prácticas tradicionales. En 1949, la "Antigua Ley de Pesca" fue sustituida por una nueva ley, que, a su vez, fue enmendada sustancialmente en 1962.

Desde el punto de vista jurídico, las pesquerías se dividen en tres categorías: "pesquerías de derechos de pesca", "pesquerías de licencia" y "otras pesquerías". Las pesquerías de licencia producen el 60% de las capturas, porcentaje al que se ha llegado con un aumento gradual de la proporción con el pasar de los años. Las pesquerías costeras se rigen por el sistema de derechos de pesca. "Los derechos comunes de pesca" autorizan a los pescadores a explotar una zona determinada de aguas, recogiendo mariscos y algas y pescando con pequeños artes fijos y con artes móviles también pesqueños, como artes de playa calados con embarcaciones sin motor. Para la pesca con artes fijos en aguas de menos de 27 m de profundidad se conceden "derechos de pesca con redes fijas". Los "derechos de explotación localizada" permiten dedicarse a la piscicultura en una zona costera determinada. Los derechos de pesca son derechos de monopolio, que autorizan a dedicarse a determinadas pesquerías en ciertas zonas de aguas públicas. Son, pues, derechos de propiedad y la mayoría de las disposiciones relativas a los terrenos se aplican también a estas aguas cuando se trata de transacciones jurídicas.

Las pesquerías principales se rigen por un sistema de licencias. La licencia de pesca exime jurídicamente a un individuo de las prohibiciones generales establecidas para conservar una población o mantener cierto orden en la explotación de los caladeros. Existen dos categorías de licencias: las concedidas por el Ministerio de Agricultura y Montes y las concedidas por los gobernadores de las prefecturas. Las primeras son necesarias en las pesquerías en que se considera preciso un control nacional, debido a las grandes dimensiones de las embarcaciones, la amplitud de la zona explotada, la existencia de acuerdos pesqueros internacionales, la naturaleza de los caladeros, etc. Diecisiete pesquerías se rigen por este tipo de licencias. Los gobernadores de las prefecturas conceden licencias a las embarcaciones a las que se dedican a pesquerías que siguen en importancia a las del grupo anterior. El número de embarcaciones a las que ha de concederse licencia en cada

pesquería se determina previa consulta con los Comités de Coordinación de la Pesca, teniendo en cuenta las dimensiones de las embarcaciones, la zona de pesca y los períodos de trabajo. Las licencias van acompañadas de restricciones relativas a zonas de pesca, temporadas de veda, tonelaje de las embarcaciones, equipo y potencia, talla mínima de los peces capturados, etc.

Todas las pesquerías japonesas están controladas singularmente y en casi todas se limita el número de embarcaciones que pueden participar. En los últimos años son pocas las pesquerías en las que se ha aumentado el número de licencias, pero ha aumentado, en cambio, el volumen de las embarcaciones y la calidad de su equipo. Dado que el esfuerzo de pesca se controla limitando el número de licencias, en varios casos se ha reducido el número de éstas cuando la explotación parecía excesiva. En algunos casos se han trasladado embarcaciones a otras pesquerías en otros, las embarcaciones obligadas a retirarse han recibido una compensación de las que permanecían en la pesquería. Pero, dado que la renovación está casi siempre garantizada, la licencia representa un valor, y se hacen inversiones y préstamos tomando como garantía la licencia. Por la concesión de licencias no se carga ningún derecho. Tal vez fuera preferible que sí se impusiera una tarifa y que los beneficios se utilizaran para compensar a los pescadores obligados a retirarse de la pesquería.

Para reducir los efectos del aumento de la potencia pesquera derivados del empleo de embarcaciones mayores y más eficaces se utiliza el sistema de suplemento de tonelaje. Para sustituir una embarcación por otra de mayores dimensiones es preciso retirar de la pesquería, comprando la licencia o por cualquier otro medio, el tonelaje extra equivalente.

El sistema utilizado en Japón responde a la situación del país, y ha tenido éxito. Otros países que piensen en limitar el número de licencias deben tener en cuenta sus problemas especiales, para juzgar si este sistema es o no adecuado.

General Review

History of Fishery Regulations

In Japan fishing has been a long established profession practised by numerous fishermen. The fishing grounds used and the resources exploited were subject to the technological level reached at a given period. Fishery regulations evolved accordingly, and as early as the 18th century fairly good control measures were developed locally in many parts of Japan to protect resources and to maintain orderly fishing operations. However, it was not until 1901 that the national Government established a unified system of regulations covering the whole country. The purpose of this legislation, called the "Old Fisheries Law," was to coordinate fishing activities mainly in coastal waters, to prevent fishing conflicts, and to protect fish resources. This Law recognized and legalized a major part of the traditional institutions and practices. Subsequently, offshore and deep-sea fisheries were developed as an outcome of the growth of the productivity of coastal fisheries and the mechanization of fishing craft. This gave rise to frequent conflicts over fishing grounds. To solve these the "Old Fisheries Law" was amended several times and various regulations regarding offshore and deep-sea fisheries were established.

In 1949 the current law was enacted to replace the Old Fisheries Law. It reflects the "democratization" of Japan after World War II, and aims at increasing fishery productivity and the democratization of the fisheries regime through coordinated use of public waters by fishermen. The new law was substantially revised in 1962 to meet the changing fisheries situation.

Current Legislation

The current legal system consists of the basic Fisheries Law and related laws, such as the Fisheries Resources Conservation Law and the Fisheries Cooperative Associations Law; in addition, a number of control and coordination regulations, based on the laws, have been issued to provide further details of operation and control.

From a legal viewpoint, as Table 1 shows, fisheries are broken down into three main categories, "Fishing Rights Fisheries," "License Fisheries," and other fisheries. In respect of fishing grounds, the coastal fisheries consist mainly of Fishing Rights Fisheries and fisheries licensed by Prefectural Governors, while the main offshore and deep-sea fisheries are licensed by the Minister of Agriculture and Forestry. The relative importance of the three types of fisheries in 1970 is shown in Table 2. In terms of production, fisheries licensed by the Minister constitute as much as 60.1%, Fishing Rights Fisheries 14.8%, fisheries licensed by Prefectural Governors 9.6%, and other fisheries 15.5%. Around 1940 "Fishing Rights Fisheries" constituted as much as 65% of the total production. Thus, the relative importance of license fisheries has gradually increased, particularly since the late 1950s. In terms of value, their relative importance is respectively 45.6, 26.4, 17.2, and 10.8%. It should be mentioned here that most of "other fisheries" were formerly free fisheries (where neither Fishing Rights nor licenses are required). More recently, however, squid angling and the saury stick-held dipnet fishery, which together constituted more than 50% of "other fisheries," have become the fishery automatically authorized by the Minister, so that the relative importance of the "free fisheries" has been considerably reduced.

In terms of the number of fishery management units (enterprises), there are approximately 6000 licensed by the Minister, representing only 2.6% of the 228,000 units in existence. The Fishing Rights Fisheries and those licensed by the Prefectural Governors are far more numerous.

Fisheries Based on Fishing Rights

The Fishing Rights system is the basic institution controlling the coastal fisheries of Japan. Fishing Rights are broken down into: Common Fishing Rights; Setnet Fishing Rights; and Demarcated Fishing Rights.

Common Fishing Rights are those that enable fishermen to exploit a certain area of water in common: to harvest shellfish, seaweeds, and other sedentary animals;

TABLE 1. System of fishery regulations in Japan.

A. Legal classification

Fishing Rights	Fishing Licenses
Exclusive rights granted by the Government to engage in specific fisheries in public waters. Treated as "Right in rem" (property rights).	All fishing activities under the licensing system are under general prohibition and specific exceptions are made by the terms of the license. Hence, a license is considered an exception from the general restrictions.

B. Illustration of the system

Fishing areas and types of fisheries	Direct regulation by Central Government	Regulation by Prefectural Government	Regulation by fishermen's organizations	Regulation by Coordination Committees
Marine		*Fishing Right granted by Prefectural Governor*		
Coastal Area				
(a) Harvesting shellfish or seaweeds		Common fishing right	Operation regulated by fishermen's coops.	Sea Area Fisheries Coordination Committees
(b) Fish culture		Demarcated fishing right		
(c) Setnet fishery		Setnet fishing right		
(d) Boat fishery				
Offshore Area	Designated by Minister and licensed by Prefectural Governors	License issued by Prefectural Governor		
Boat fishery				Central Fisheries Coordination Committee
Deap-Sea Area	Licensed by Minister of Agriculture and Forestry			
Boat fishery				
Freshwater		(a) Common fishing right (b) Demarcated fishing right		Freshwater Fisheries Control Committee

to operate small types of fixed fishing equipment; or to operate small mobile fisheries such as beach seines and seines set from nonmotorized craft.

Common Fishing Rights are granted only to fishermen's cooperatives made up of coastal fishermen. Details of operation of Common Fishing Rights are decided at a general meeting of the fishermen's cooperative. Common Fishing Rights, the duration of which is usually 10 years, have been granted for all the coastal waters of Japan.

Setnet Fishing Rights are rights to operate setnets where the main part of the net is fixed in water more than 27 m deep. These rights are granted to fishermen or entrepreneurs who meet certain requirements, i.e. who agree to abide by fishery regulations, not to hinder the democratization of fishing communities, etc. First preference is given to fishermen's cooperatives, and second, to fishing cooperatives, whose members live in the local coastal area. The duration of the rights is usually 5 years.

Demarcated Fishing Rights enable holders to engage in fish culture within a given coastal area. In the case of marine fish culture, including breakwater and pearl culture, the rights are granted to applicants who fulfil certain qualifications. For laver culture, oyster culture, and yellowtail culture, priority is given to fishermen's cooperatives in the local area. The members of the fishermen's cooperatives engage in culture operation according to regulations decided upon by the cooperatives. Duration of the rights is 10 years for pearl culture and for marine fish culture with breakwaters, and 5 years for other culture operations.

Fishing Rights are monopolistic and exclusive rights to engage in certain fisheries in certain areas of public waters. Consequently, they are regarded as "Rights in rem" (property rights), and the same provisions concerning land are applied to them in legal transactions, except that there are certain restrictions on lending, transfer, and

Table 2. Production by fisheries under fishing rights and licenses (1970).

	No. of rights or licenses	Landings (thousand metric tons)	Value (Billion Yen[a])
Fishing rights fisheries		1,372 (14.8)	255.2 (26.4)
Marine fisheries	23,501	1,260 (13.5)	214.5 (22.2)
Common fishing right	8,046	560	52.5
Setnet fishing right	1,608	151	26.7
Demarcated fishing right	13,847	549	135.3
Freshwater fisheries	4,102	112 (1.3)	40.7 (4.2)
Common fishing right	1,120	64	9.0
Demarcated fishing right	2,982	48	31.7
Fisheries under the Minister's licenses	6,994	5,610 (60.1)	442.5 (45.6)
Fisheries under Prefectural Governors' licenses	121,000	892 (9.6)	166.7 (17.2)
Marine fisheries	103,000	836 (9.0)	158.7 (16.4)
Freshwater fisheries	18,000	56 (0.6)	8.0 (0.8)
Others		1,441 (15.5)	104.8 (10.8)
Total		9,315 (100%)	969.2 (100%)

[a] \$1.00 (US) = 300 Yen, approximately.

mortgage. Prior to granting fishing rights the Government (normally the Prefectural Governors) draws up, after consultation with the "sea area fisheries coordination committee," an overall program for the utilization of each area, and defines the rights to be granted. These fishing rights are then granted to qualified applicants according to the established priorities.

Fishermen's cooperatives that have been granted Common Fishing Rights or Demarcated Fishing Rights may, by contract, give outside fishermen "Entry Rights," which enable them to operate in the area.

Fisheries Based on Fishing Licenses

Legally, a fishing license exempts an individual from general prohibitions declared for the purpose of conservations or the maintenance of order in the exploitation of fishing grounds. There are two categories of fishing licenses: those granted by the Minister of Agriculture and Forestry, and those granted by Prefectural Governors.

Fisheries for which licenses by the Minister of Agriculture and Forestry are required — Fishing licenses granted by the Minister are required in order to engage in fisheries for which national control is considered necessary, because of the large size of the vessels employed, the wide area of fishing operations, the existence of international fisheries agreements, the nature of the fishing grounds, etc. These fisheries are designated by the National Government by means of a cabinet ordinance, after consultation with the Central Fisheries Coordination Committee. The following 17 fisheries[2] have been designated according to the above procedure: 1, offshore trawl fisheries employing vessels of 15 gross tons or more; 2, trawl fisheries in the Yellow Sea and the East China Sea employing vessels of 15 gross tons or more; 3, deep-sea trawl fisheries employing vessels of 15 gross tons or more; 4, North Pacific longline/gillnet fishery; 5, factoryship trawl fisheries; 6, large or medium purse seine fisheries normally employing vessels of 40 gross tons or more, but 15 gross tons or more for certain fishing grounds; 7, large-scale whaling, with catcher boats of 100 gross tons or more; 8, small-scale whaling; 9, factoryship whaling; 10, deep-sea tuna longline fisheries, with vessels of 70 gross tons or more; 11, offshore tuna longline fisheries, with vessels from 20 to 70 gross tons; 12, factoryship tuna longline fisheries; 13, medium-scale salmon gillnet fisheries, with vessels of 30 gross tons or more; 14, medium-scale salmon longline fisheries, with vessels of 10 gross tons or more; 15, factoryship salmon fisheries; 16, factoryship crab fishery; and 17, pearl shell fisheries.

Licenses are issued both on fisherman/entrepreneur and on vessel bases. Licenses are renewed every 5 years, except in the salmon fisheries and in whaling, where, because of international agreements on the amount of catch, licenses have to be reviewed every year.

The procedures for licensing are the following:

(a) The number of vessels to be licensed is determined for each fishery after consultation with the Central Fisheries

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[2] All these fisheries are defined in the relevant Laws and Regulations by size of vessel, fishing gear, equipment, or fishing area, but details are not given in this paper.

Coordination Committee by size-class of vessels, by fishing area, and by periods of operation. The decision on the number of the vessels is based on such considerations as conservation of fish resources, maintenance of order in fishing operations, the number of fishing units already engaged in the fishery, and managerial and financial aspects.

(b) The number of vessels to be licensed is announced publicly.

(c) Applications for licenses are made.

(d) The Government examines the applicants' qualifications, which include evidence that: the applicants will abide by the laws and regulations concerning fisheries and labor; the vessels meet necessary technical standards; applicants possess sufficient capital to engage in the fishery concerned.

(e) Those who meet the qualifications are given licenses according to the following order of priorities: first priority is given to those already engaged in the fishery in question; if there is room for new entrants, an important consideration is whether the applicant is transferring from another fishery and whether such a transfer would have a favorable impact by decreasing pressure on resources and by lessening operational conflicts among fishermen. Favorable consideration is also given when a fisherman who is employed in the fishery in question proposes to become an independent entrepreneur by obtaining the license.

The above procedure is used at the time of general renewal of licenses. At other times licenses are granted automatically in the following cases: when someone engaged in the fishery whose vessel has sunk or ceases to be used applies for a license for a vessel of the same size; when an applicant has purchased a vessel already licensed for the fishery in question. (Advantage is taken of this procedure in order to increase the size of vessels. The licenses are transferable at a certain market price; this aspect will be touched on later in this paper.)

Fisheries for which fishing licenses are required from Prefectural Governors — The fisheries for which licenses are issued by Prefectural Governors are broken down legally into those specifically designated by the Minister of Agriculture and Forestry to be licensed by Prefectural Governors, and those licensed by Prefectural Governors on their own initiative.

The first category includes fisheries considered sufficiently important for the coordination of nationwide activities that the Minister fixes the maximum number of vessels to be licensed for each of the prefectures. These fisheries comprise those next in importance to fisheries licensed by the Minister. They include small-scale trawl fisheries employing vessels of 15 gross tons or more, medium-scale purse seine fisheries with vessels from 5 to 40 gross tons, trawl fisheries in the Seto Inland Sea with vessels of 5 gross tons or more, and small-scale salmon gillnet fisheries with vessels of less than 30 gross tons.

The second category covers those fisheries that Prefectural Governors feel should be regulated in order to coordinate fishing operations at the prefectural level — coastal or offshore fisheries such as gillnet fisheries, troll fisheries, pot fisheries, octopus fisheries, and fisheries using diving equipment. Governors' Licenses are issued, as in the case of Minister's Licenses, both on fisherman/entrepreneur and on vessel bases. Where the total number of vessels in a fishery is fixed for the purpose of coordinating fishing operations, certain qualifications and priorities are used.

Restrictions and prohibitions — Fisheries licenses are subject to certain restrictions and prohibitions, which constitute a part of the license. Some examples are

(a) Prohibited areas: Operation in certain areas is prohibited in trawl, purse seine, and salmon fisheries, with a view to coordinating with the operation of coastal fisheries.

(b) Closed seasons: During certain periods of the year fishing is prohibited in offshore trawl fisheries, small-scale trawl fisheries, purse seine fisheries, and saury stick-held dipnet fisheries, for resource conservation and the coordination of fishing operations among fishermen.

(c) Restrictions or prohibitions regarding vessels or equipment: These include restrictions on vessel tonnage and engine horsepower in small-scale trawl fisheries; mesh size regulations and limitations on the number of nets used in trawl fisheries in the Yellow Sea and the East China Sea and the salmon gillnet fishery; and limitations on the power of lights used in purse seine fisheries and saury stick-held dipnet fisheries.

(d) Other: Restrictions are placed on species that may be caught, minimum sizes of fish retained, and ports of landing; taking female crabs is prohibited, etc.

FISHERIES COORDINATION COMMITTEES

The fisheries control system aims at increased fishery production and the democratization of fisheries. The fisheries coordination committees in which fishermen/entrepreneurs actively participate are instruments for achieving these aims.

There are three kinds of fisheries coordination committees: Sea Area Fisheries Coordination Committees, Joint Sea Area Fisheries Coordination Committees, and the Central Fisheries Coordination Committee.

A *Sea Area Fisheries Coordination Committee* has been set up in each of 64 areas (in principle, one for each prefecture). The Committee functions to advise the Prefectural Governor to draw up an overall plan for utilization of fishing grounds, and to establish or amend Prefectural Fisheries Regulations that provide for granting of fishing rights or licenses, or to take other legal action; to prohibit or control fishing operations whenever this is necessary to ensure proper use of fishing rights, to coordinate fishing operations or to prevent conflicts in the use of fishing grounds; and to arbitrate the establishment or amendment of the rights of a third party to participate in fishing in the area concerned.

The Committee normally consists of 15 members; nine are elected from among fishermen/entrepreneurs and employee fishermen, four are men with knowledge of and experience in fisheries, appointed by the Governor, and two represent interests of the community, also appointed by the Governor. The term of office is 4 years.

A *Joint Sea Area Fisheries Coordination Committee* is set up as needed, to deal with specific problems arising between sea areas. A Committee consists of members appointed from among the members of the Sea Area Fisheries Coordination Committees concerned, equal numbers of members from each. Joint Sea Area Fisheries Coordination Committees have been established in the Seto Inland Sea, the Ariake Sea, and the Genkai, where fishing grounds are exploited by fishermen from a number of different sea areas.

The *Central Fisheries Coordination Committee* is an advisory organ for the Minister of Agriculture and Forestry, and is consulted on certain important matters concerning enforcement of the Fisheries Law. The Committee consists of 25 members, 15 representatives of the fishing industry, and 10 members with knowledge of and experience in fisheries.

The Minister consults this Committee when he issues or changes ministerial regulations dealing with the designation of fisheries to be licensed by the Minister, such as the number of vessels to be licensed and the establishment of criteria for licensing and regulatory measures.

REGULATIONS OF FRESHWATER FISHERIES

Special features of the inland fisheries control system include coordination of interests of commercial fishermen and sports fishermen, and provisions for obligatory fish breeding activities to be carried out by holders of fishing rights.

Fishing Operations under the Current System of Regulations

JAPANESE FISHERIES THAT PERMIT NO NEW ENTRIES

The Japanese fisheries, including the coastal, offshore, and deep-sea fisheries, are controlled and coordinated as a unit. This reflects the fact that in their development from coastal fisheries to offshore and deep-sea fisheries they

TABLE 3. Number of fishing management units (in thousands).

Year	1960	1965	1966	1967	1968	1969	1970
Coastal fisheries							
Boat							
Nonpowered	70.0 (29.8)	32.4 (14.5)	26.3 (11.7)	22.6 (9.9)	20.1 (8.8)	15.5 (6.7)	12.9 (5.7)
Powered	94.0 (40.0)	111.8 (49.9)	115.5 (51.6)	119.5 (52.6)	126.1 (55.1)	131.3 (56.6)	129.9 (56.9)
Other							
Setnet, Beach seine	10.4 (4.4)	8.6 (3.9)	8.4 (3.7)	8.2 (3.6)	6.9 (3.0)	7.3 (3.1)	7.4 (3.2)
Marine culture	50.8 (21.7)	62.0 (27.7)	64.7 (28.9)	67.9 (29.8)	66.5 (29.1)	68.5 (29.5)	68.4 (30.0)
TOTAL	225.2 (95.9)	214.8 (96.0)	214.9 (95.9)	218.2 (95.9)	219.6 (96.0)	222.6 (95.9)	218.6 (95.8)
Offshore and Deep-Sea Fishing	9.6 (4.1)	8.9 (4.0)	9.1 (4.1)	9.4 (4.1)	9.2 (4.0)	9.6 (4.1)	9.6 (4.2)
Total (all fisheries)	234.8 (100.0)	223.7 (100.0)	224.0 (100.0)	227.6 (100.0)	228.8 (100.0)	232.2 (100.0)	228.2 (100.0)

TABLE 4. Number of fishing vessels (in thousands).

Year	1960	1965	1966	1967	1968	1969	1970
Coastal vessels (less than 10 tons)	344.8	363.6	361.5	360.8	358.1	353.2	353.3
Offshore and deep-sea vessels (over 10 tons)	15.9	17.5	17.6	17.6	17.4	17.3	17.3
Total	360.7	381.1	379.1	378.4	375.5	370.5	370.6

have always faced the problems of fishing effort in relation to fish resources available, and conflicts of interest among fishermen both within the same fishery and between different fisheries. Almost all fisheries are controlled and limited. The only fishery of importance where entry is still open is the coastal angling fishery using small boats. In most other fisheries there have been few if any increases in the numbers of licenses issued. Although the domestic demand for fish has considerably increased in relation to supply in the last 10 years, causing a considerable rise in fish prices and increased imports, the total number of fishing units decreased from 235,000 in 1960 to 228,000 in 1970 (Table 3). During the same period, the number of units engaged in offshore and deep-sea fishing with vessels of more than 10 gross tons has scarcely changed. The total number of fishing vessels increased slightly from 1960 to 1965, but since then a downward trend can be observed, both for coastal and for offshore/deep-sea fisheries (Table 4). In particular, there is very little possibility of new entries in fisheries licensed by the Minister, since the number of vessels is fixed with respect to each fishery and, as noted above, at the time of renewal of licenses priority is given to those who are already engaged in that fishery. Thus, to enter these fisheries an individual must first have been a fisherman employed in the sector, and he must purchase a fishing license from an existing license holder.

In fisheries under ministerial license these rules have served to control fishing effort, to expand individual enterprises, and to increase the size of fishing vessels and modernize their equipment.

CONTROL OF FISHING EFFORT

Fishing effort is controlled when it is considered to be too great for the available fish resources in the light of results of research, or when reduction of fishing effort is required as a result of international agreements. In fisheries licensed by the Minister there have been many instances where fishing effort has been cut by a reduction of the number of fishing vessels. Two different patterns have been employed. Where other fisheries were capable of expanding their effort, the Government arranged for the excess fishing power to be transferred to them. Where such an arrangement was not possible, fishermen/entrepreneurs who had to leave the fishery were compensated by those who remained, and benefited by the reduction of fishing effort.

The Fisheries Law stipulates that at the time of renewal of a license, if the number of applicants engaged in the

TABLE 5. Number of licensed vessels in the offshore trawl fishery.

Year	No. vessels	Avg. vessel tonnage	Total tonnage (in thousand tons)
1951	2836	29	81
1955	1527	35	54
1960	1308	42	55
1965	1091	49	54
1970	990	56	56

TABLE 6. Tonnage classification of deep-sea tuna vessels.[a]

Tonnage class	Upper limit of enlargement	Fishing season
70–119.99	120	All year round
120–149.99	150	
150–179.99	180	
180–209.99	210	
210–239.99	240	
240–269.99	270	
270–299.99	300	
300–329.99	330	
330–359.99	360	
360–389.99	390	
390–419.99	420	
420–449.99	450	
Over 450	Over 450	
70– 84.99	85	6 or 9 months

[a] The number of vessels to be licensed is announced for each tonnage class.

fishery exceeds the announced number of vessels to be licensed, new licenses will be issued taking into consideration the number of vessels owned by the applicant, the fishing record of the applicant, and the extent to which he depends on the fishery. Licenses are renewed every 5 years without charge for the number of vessels considered reasonable from the viewpoint of resource conservation; legally, therefore, the Minister can reduce the number of vessels without any compensation to former license holders. However, because of the priority given to those actually engaged in the fishing, continuation of a license is practically assured. Investments are made and loans are extended by financial institutions taking licenses as security. Without the system of compensation, nonrenewal of a license would be a considerable financial loss to its holder.

Reduction of the number of fishing vessels by means of transfer to other fisheries — In the offshore trawl fishery, which is a long established one, the number of vessels licensed increased rapidly in the years of food shortage immediately after the second world war, and excessive fishing effort became noticeable around 1951. Since 1953 the Government has taken every opportunity to reduce the number of vessels.

In 1953 offshore trawling vessels were transferred to the tuna longline fishery, which at that time was expanding rapidly. Government subsidies were given for remodelling the trawlers into tuna boats. By 1955 the trawler fleet was reduced by 111 vessels. In 1954, when factoryship salmon fishing started, licenses for the catcher boats were granted only to those who withdrew from the offshore trawling. As a result there were 318 fewer trawlers by 1956. When deep-sea trawling developed in the North Pacific Area from 1961 to 1964, 126 offshore trawlers were withdrawn and transferred to the new operation. Also, when licenses were issued for deep-sea trawling in the South Pacific area, some were set aside to decrease the number of offshore trawlers by requiring the withdrawal of at least 50 gross tons. Furthermore, an offshore trawler owner was required to withdraw a corresponding tonnage from offshore trawling when enlarging the size of his vessel. By these measures the number of licensed vessels decreased from 2836 in 1951 to 990 in 1970 (Table 5).

It should be noted that in recent years enlargement of vessels has been aimed mainly at improving accommodations for the crew, and does not imply any great increase of fishing power of the vessels.

In order to ensure effective transfer measures it is necessary to place a new fishery under government control at an early stage of its development, and to specify the conditions of entry.

The normal procedure followed by the government is first to allow a limited number of vessels to carry out exploratory fishing. If the fishery is found to be feasible, it is placed under government regulation, and licenses are issued only under certain conditions. Later the total number of licenses may be gradually increased in the light of a careful review of operational results. Thus adequate but not excessive fishing effort is maintained.

Reduction of the number of vessels by means other than transfer — As the possibility of developing new fisheries has gradually decreased, it has become difficult to reduce fishing effort by means of transfer to other fisheries. It has therefore become necessary to reduce fishing effort by other means. This has created problems due to the practice of respecting the right of those already engaged in the fishery. When the system of regulations was established it was suggested that fees be charged for granting fishing rights and licenses. This proposal was abandoned because of the strong opposition of fishermen, who maintained that it would cause accumulation of rights and licenses by those who have financial power, and that the fees might not be fed back to the fishing industry. Since license holders do not pay fees, the Government is not legally required to pay compensation for cancelling the licenses. Therefore, reduction of fishing effort has to be followed by mutual compensation among fishermen entrepreneurs. To facilitate this, however, the Government has assisted the industry by arranging loans and by granting subsidies for interest payments.

The trawl fishery in the East China Sea and the Yellow Sea is cited as an example. Although in this fishery some reduction has been made by transfer of vessels to the deep-sea trawl fishery and by strict mesh size regulations, fishing effort is still considered excessive. The financial position of fishermen entrepreneurs has been deteriorating, and this has prompted the industry to reduce the fishing effort by 15% of its own accord. The Government assists the industry by arranging loans and interest subsidies for those who remain, and must pay compensation to operators forced out.

In the light of the above experience, it appears that it would have been better if a system had been provided in the law so that fees are charged when granting fishing rights and licenses, and the income used for compensation of those leaving. The principle of respecting the right of those currently engaged in the fishery has succeeded in preventing new entrants, but on the other hand has constituted an obstacle to the reduction of fishing effort.

IMPROVEMENT OF EFFICIENCY OF INDIVIDUAL VESSELS

Fishing effort is controlled primarily by limiting the number of fishing vessels licensed, by size (gross tonnage). When required, additional restrictions are made regarding fishing grounds, gear, seasons, number of nets, mesh size, horsepower, etc.

Direct control of the amount of catch has been exercised only on those species such as salmon and whales for which the Government has obligation by international agreement to limit the catch. Technological developments and increasing distances to fishing grounds usually require progressively larger fishing vessels, which normally result in an increase in total fishing effort. A "tonnage supplement system" has been developed to deal with this.

The Fisheries Law provides that licenses can be inherited in case of the death or merger of license holders, and that a license for the same fishery can be transferred from a vessel that founders or ceases to be used to another vessel having the same specifications. It also prescribes that the Government shall issue a license to anyone who purchases or rents a licensed vessel and applies for the fishery. The Government can give permission for alteration of the specifications contained in the license, such as increase of tonnage of the vessel, change of the fishing area, etc.

Based on these provisions, certain procedures have been established for the enlargement of individual fishing vessels. As a typical case, the deep-sea tuna fishery is mentioned; here vessels are classified into several tonnage groups, as shown in Table 6. If the license holder wishes to replace a vessel of 240 tons by one of 269 tons, the application would be approved without the applicant being obliged to withdraw the difference in gross tonnage since this increase would keep the vessel in the same tonnage class. However, if the applicant wishes to replace a 240-ton vessel by a 370-ton vessel (moving to a higher tonnage class), it is necessary for him to withdraw at least 120 tons more, the difference between the upper limits of the two classes. However, under this system it is not permitted to enlarge a vessel beyond the upper limit of the class containing vessels twice as big as the original vessel. Since most vessels are close to the upper limit of their classes it is usually not possible for them to increase more than twice in size. The tonnage retired must come from licensed vessels in the same fishery that have not been out of operation for more than a year. The tonnage of the vessels withdrawn can be used as the applicant wishes. For example, if a vessel of 149 tons is retired, 150 tons can be used to supplementary tonnage and the applicant can use 50 tons each for the enlargement of three vessels.

This is the so-called "tonnage supplement system" and the increase in size of vessels according to this system is called "enlargement by tonnage supplement." Special rates are used in adjusting the supplemental tonnage ni certain fisheries where the tonnage of fishing vessels does not relate proportionately to fish catching capacity.

Licenses and the licensed vessels required for tonnage supplements are usually purchased through brokers engaged in this business. Purchases are made on the basis of price per vessel ton. The more profitable the fishery or the more advantageous the enlargement of the vessel, the higher the prices, and these therefore fluctuate according to the state of the fishery. For example, the price per ton for deep-sea tuna vessels rose each year until 1963 when it reached $1500 (US), but it fell to $470 (US) in 1965, reflecting the deteriorating profitability of the fishery as a result of the decrease in the resource and the fall in tuna prices. Recently, it has risen again to more than $1000 (US) Licenses are regarded as the "property" of their holders. Thus, although it is possible for fishermen/entrepreneurs to increase the number of their vessels, to enlarge the size of vessels, or to enter a licensed fishery, costs are considerable, and constitute a financial burden on the enterprise.

THE LICENSE SYSTEM AND FREE COMPETITION

There is need to ensure free competition among enterprises in fisheries in order to promote technical development even while total fishing effort is strictly regulated. Each country must find a system appropriate to it, since technical, social, and economic conditions in the fisheries differ widely. In Japan the current system has evolved against the historical background that the Japanese fisheries have gradually developed from coastal to offshore and then to deep-sea fisheries. The amount of fishing effort has been brought under control in all three sectors in an integrated manner, with due consideration given to the rights of fishermen/entrepreneurs who are already engaged in the fishery, to the need for limitation of new entries, and the desirability of rationalizing entreprises and the competition among them. The system of tonnage supplements has been one means of ensuring competition among fishermen/entrepreneurs and of encouraging technological development. As the enlargement of fishing vessels has progressed, the total number of vessels has decreased, and the total fishing effort has been maintained at almost the same level.

Personal Views and Observations on Fishery Regulation Systems in the Light of Japanese Experience

SIGNIFICANCE OF THE LICENSE SYSTEM

The purpose of controlling fisheries is twofold. One purpose referes to resource management, to ensure the "maximum sustained yield" by preventing either overexploitation or underexploitation of resources. Another is to guide the fishing industry so that both enterprises and fishermen can play their proper roles in the national and international economies. The Fisheries Law therefore aims at the coordinated use of fishing grounds to increase fishing productivity, to provide a basis for resource conservation, to coordinate fishing activities, and to maintain order among fishermen and entrepreneurs.

Generally speaking, direct catch controls may be the simplest and most effective way to manage resources. This can be done by establishing a maximum total catch and leaving the catch of individual fishing vessels to free competition (the so-called "Olympic method"); or by setting quotas for individual vessels.

The former method greatly facilitates technical advancement by encouraging competition among enterprises, but it eventually leads to excessive competition, overinvestment, and financial difficulties. In the latter method competition among enterprises is not created so acutely, but since new entries are freely allowed, profitability falls and the industry stagnates. When fish prices rise constantly, as they do in Japan, new entrants will always be attracted, causing reduction of quotas for individual vessels. This is clearly an overinvestment from the social viewpoint. Some sort of limitation on new entries is therefore required for both resource management and socioeconomic considerations.

With respect to resource management, it may be argued that the Japanese system on controlling fishing effort by means of total tonnage allowed in a fishery is less effective than a direct catch control. However, the present level of skill in making estimates of resource size makes management based on catch control less accurate than one might expect in many cases. Also, from the viewpoint of enforcement of regulations, control of the number of vessels and their tonnage is much easier than control of catch by individual vessels, at least in Japan.

Although enterprises are limited by the total tonnage allowed in a fishery, there remains enough room for competition among them to encourage technological development, and this has led to fewer vessels of larger size. At the time of renewal of licenses the total number of vessels is determined in respect of the management of fish resources and commercial enterprises. In the case of new fisheries the number can be increased gradually to avoid overexploitation and overinvestment.

LICENSE FEES

Restricted entry sometimes results in license holders enjoying more than average profits. One way to deal with such a situation is for the government to regain the excess profits in the form of license fees. If such fees are levied equitably there will not be any fisheries that are particularly profitable, and the reduction or transfer of fishing effort will then be easier. It will also be possible to use the income from license fees to compensate fishermen and entrepreneurs who withdraw from the fishery.

Although the system is not used in Japan, tenders for licenses for fixed terms constitute a means of fixing reasonable fees. In order to ensure equitable distributions of licenses, it would be necessary under such a system to limit the number of licenses for individual fishermen/entrepreneurs to one each, and to make payment easier by allowing them to be made by instalments. When the term expired tenders would be invited again. Anybody could bid and there would be no discrimination against the new entrants, but those already engaged in the fishery would usually be in a more favorable financial position.

The Japanese experience suggests that consideration of a license fee system through tender would be worthwhile in countries where limited entry fishery regulations are being newly established.

The modernization and increased efficiency of fishing vessels has been encouraged in Japan by shortages of labor and the consequent rise of wage levels and need to improve labor conditions. A system of license fees stimulates such improvements.

VARIOUS FORMS OF RESTRICTIONS AND PROHIBITIONS

Japanese regulations include detailed restrictions and prohibitions for each fishery, e.g. the maximum number of vessels for each tonnage class, the legal fishing grounds, gear, seasons, amount of catch, etc. The more detailed and complex regulations are, the more opportunities arise for violations, and the more difficult enforcement becomes. It is thus desirable to keep the regulations to the minimum essentials.

From the viewpoint of administering the license system it would be desirable to restrict control to the indirect fixing of catch by limitation of fishing effort, and not to use direct catch controls except where considerable fluctuations of resources are expected. However, indirect control of fishing effort by fixing the total tonnage of fishing vessels requires the "tonnage supplement system" to facilitate the free choice of vessel size, thus contributing to technological advances. When, as a result of enlargement of size of vessels, an increase in fishing effort occurs that is considered to be too great, the supplementary tonnage required should be adjusted upward so that total fishing effort can be kept at the same level.

If the upper limit of enlargement of fishing vessels is set too low, owners may try to put extra equipment on the vessel and to enlarge the fish hold beyond proper capacity, so that accidents occur. It is advisable to fix the maximum limit of vessel tonnage at reasonable levels in consideration of distances to the fishing grounds, fishing methods, and equipment used.

The Japanese license system started as a measure to prevent conflicts among fishermen/entrepreneurs and to encourage balanced development of the industry. The system evolved further by aiming at the coordinated utilization and management of fish resources. The character of the system is fixed by the special circumstances in Japan, where from ancient times people have been heavy consumers of fish, where almost all fishes are marketable, and demands for various species can be substituted for each other. Under these circumstances the approach to resource management has been somewhat different in Japan compared with other countries. As an example, the regulations concerning the purse-seine fisheries for sardines, mackerels, and horse mackerels are joint limitations on fishing effort for all these species, which are thus treated as a single mixed resource. This is because they migrate in the same area and there is evidence of a close mutual relation in their abundance fluctuations. Only for certain species of high price such as crabs, for which fishing effort may therefore be concentrated, have additional measures such as catch limitation had to be taken. In this respect the Japanese fishing situation is different from that of many other countries where fishing has often developed on a single species. Then a license system like that developed in Japan might not be applicable.

Report on Technical Session II

1. Following the discussions during Session I, the Conference considered the economic and institutional aspects of management and development of fisheries in a world perspective. While there was recognition of the differences in problems and potential solutions from region to region and country to country, there was also appreciation of the common underlying factors.

General Objectives of Management

2. There is a complex of objectives as well as of methods. The objectives vary from country to country and will vary within countries in the light of changing circumstances. Allowance has to be made, too, for the social as well as the economic factors. In some cases the aim is to produce food as cheaply as possible, or perhaps to increase earnings of foreign exchange by export. In other instances maintenance of employment, stabilization of communities, or keeping a way of life may be the basic objectives.

3. Countries should weigh the various objectives because fisheries must compete for resources of money and manpower with other sectors of the national economy. If the fishery is expanded too far beyond the point of maximum economic yield, there will be long-term difficulties, because the human and other resources might be used more effectively elsewhere.

4. Management should, as a rule, encourage technological improvements, but at the same time it must be appreciated that in certain conditions such improvements may involve displacing people who cannot easily find satisfactory alternative activities.

5. In setting the objectives for management, the needs for integrated planning and development of the fishery within the respective national economics was emphasized.

Gains and Costs of Management

6. The gains of good management are likely to be large, sometimes even involving the survival of a fishery. However, gains are not merely monetary, but also included in the welfare of the fishermen, the community and the state.

7. It was recognized that the advantages of management are more difficult to realize where there is a lack of mobility in the fishery sector.

8. During the discussion reference was made to the FAO studies of Atlantic cod and Peruvian anchovies and the estimates of very large monetary gains from a reduction of fishing effort.

9. Amongst the specific benefits is the improvement in the economic strength of the fishery, enabling it to withstand fluctuations in supply more easily.

10. Benefits are likely to be greater, if action is taken sufficiently early to prevent too much overcapacity. In the past, difficulties have developed because the fishermen did not wish to reduce effort until they were seriously hurt, while the biologists were supposed to provide definite proof of damage to the stock rather than reasonable probability.

However, the situation is changing, with fishermen becoming more realistic and the scientists providing estimates and advice at an earlier stage.

11. It was pointed out that there were circumstances where some overcapacity may be desirable; for example, where there are significant variations in annual catches. The Pacific salmon industry is a good example.

12. Once overcapacity exists, governments are under pressure not only to allow excessive effort to continue, but even to subsidize it.

13. In view of increasing demand in relation to supply, the value of fish is likely to rise sharply in both domestic and foreign markets. This will tend to increase further the investment in factors of production without corresponding increase in catch, thus reducing efficiency and even endangering stocks. This factor alone would indicate the benefits of a management system.

14. The costs of research for resource management are not large in relation to the advantages, but there is a difference between fisheries long under way and those that are being newly developed. In the former case, some information is relatively easy to obtain, while in the latter case it may be costly to determine abundance and distribution of stocks.

Timing of Regulatory Measures

15. An ideal development of a new fishery would include an exploration period, rapid early development, then a gradual application of a brake on expansion as the target level is approached — whether this be maximum sustainable yield, maximum economic rent, or maxmium employment. The dangers of slowing down too soon, and of letting expansion go too far, were both emphasized. However, experience to date is that overinvestment is much the more common situation, so that controls are usually applied only where a fishery is already badly mismanaged.

16. Part of the reason for this lateness derives from the difficulty of identifying an overexploitation situation before actually getting into it. However, reluctance to take difficult and unpopular action is even more important.

17. Contributing to this are the long intervals between ordering new equipment (vessels especially) and getting delivery, and between delivery, and the effect of the additional equipment on the fish resource becoming apparent. There is usually also a lag between recognition of a need for restraint and the implementation of necessary measures—particularly in international fisheries.

18. Both surplus equipment (vessels, plants, cold storage, etc.) and surplus personnel (especially the fishermen themselves) are frequently difficult to deploy into other

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fisheries or other industries. This is a serious problem in even the most "developed" countries, but is especially acute in some of the less developed ones.

19. As a guide to when a brake should be applied to expansion it was suggested that a possible indicator would be when an increase in fishing effort no longer produces a proportional increase in catch. Actually this occurs quite early in many fisheries, long before any desired maximum has been approached.

20. The "experimental management" approach seems applicable here — a cautious increase in catch until an undesirable trend is apparent, then some retreat. This applies best to stocks with fast growth and rapid turnover, and fails with long-lived species like cod or ocean perch because of the "fishing-up" effect.

21. The point was made that in some countries new fisheries are established by factors of production (boats, fishermen) that have become surplus in established fisheries. Hence to hold an established fishery to an optimum level could slow down or prevent the development of new kinds.

Reconciliation of Different Interests

22. The competing interests of local and long-range fisheries were discussed. One view was that instead of building more large long-range vessels, the developed countries should invest in local shore facilities and smaller ships, and thus gradually build up a local capacity. The view was also put forth that shore-based fisheries may in the long run be more efficient than long-distance fleets.

23. Even within a country there can be serious conflicts between different types of fishermen, which require management devices. Examples are the taking of cod by traps and by trawling, and taking herring by gillnet and by purse seine.

24. In the conflict (often more apparent than real) between commercial and recreational uses of aquatic resources, it is difficult to find an economic basis for decision. The commercial fishery may be producing almost no net economic rent, while for the sport fishery no accepted basis of economic valuation exists. Thus when a decision is made it is apt to be based to a great extent on political or even emotional grounds.

25. Another conflict is between fisheries (whether commercial or recreational) and other uses of resources such as power development, extraction of oil from the sea bed, and so on.

Methods of Management

26. For the general case of actual or imminent overexploitation of international fisheries, the opinion was expressed that the best practical solution available today is national quotas. The reward here (maintenance of a high level of yield and the opportunities for each country to pursue their individual objectives) is much greater than the difficulties, great though these may be. Difficulties include getting an agreed basis for quotas, provision for increased or new participation by some countries, and the danger that too great subdivision might make participation of well-established industries too small to be economic.

27. The experience of Japan, South Africa, Canada, and Norway in limitation of fishing capacity was referred to. Although there are some undesirable side-effects, these programs can be considered successful to date. Trouble may arise because there is competition with other nations for a limited supply, and in most cases there are no national quotas so far.

28. Monitoring systems were suggested for two purposes: to indicate when an economic rent emerges in a managed fishery; and to show when a fishing concern is in incipient trouble so that remedial action can be taken before it goes bankrupt.

29. The utility of equilibrium models was questioned, but they were defended on the ground that fluctuations — sometimes quite large ones — are always assumed to be superimposed on the trend line. One speaker felt that equilibrium models are alright for single stocks but useless for fisheries that attack many species in common.

Aspects of Development

30. In developing countries the expansion of fisheries competes for resources with other kinds of development, and frequently it does not stand very high on the priority list. Changes in government or financial crises may mean rapid changes in the effort devoted to fisheries. To improve the political climate for development of fishing one suggestion was a regional plan with several countries participating. Another suggestion was a plan to be drafted by invited experts plus knowledgeable local people, which would have a good chance of commanding respect and support from both government and the private sector.

31. In development plans, ships and gear usually are emphasized, with little or no attention to the land-based structure — ports, plants, handling, transportation, and marketing. The need for further attention and assistance with matters of fisheries training was also emphasized.

32. There was a complaint that in some countries too many government departments are concerned with various aspects of the fishing industry, making it difficult to obtain integrated action, or even any action at all.

33. While exploration for new stocks is a proper function for government, in some places the flow of information from research vessels to industry needs to be improved.

FAO Technical Conference on
Fishery Management and Development

TECHNICAL SESSION III

Exploiting New Resources and
Developing Fishery Industries

CHAIRMAN: M. FILA, POLAND

Structural Problems and the Need for Structural Planning in Fisheries Development

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ONARHEIM, T. 1973. Structural problems and the need for structural planning in fisheries development. J. Fish. Res. Board Can. 30: 2100–2108.

Planning within a structural and geographical macro-perspective — defining desirable relations between regions, countries, and industrial sectors and units — should precede planning at the microlevel. Development aid by industrialized countries to the developing world should be conceived on the basis of an international division of labor and distribution of joint natural resources which appear optimal from a global standpoint. The global solution constitutes a point of departure for suboptimizing down the scale of geographical and sectoral levels.

Managing common property fisheries to maximize net economic returns (i.e. by setting yield targets below the maximum sustained yield level) makes sense for the industrialized countries. As long as people in developing countries go hungry, however, and production of food resources below the maximum level cannot be made up by imports, a level of fishery resource exploitation below the maximum sustained yield does not seem to be justifiable on a global basis. Neither can maximum economic efficiency be accepted as the governing criterion for management, since this would undoubtedly work toward the creation of a virtual monopoly of exploitation by the countries with the most sophisticated technologies, in the absence of an international mechanism to guarantee that resulting economies would benefit others as well.

Global redistribution of fish production and processing may be the most effective form of development aid, as the cost of "aid" given in this manner may be lower than that of financial and technical aid made available by industrialized countries. The "sacrifices" implied by this redistribution of natural wealth would not be great, as support for unprofitable or marginally profitable fisheries has often been no more than an impediment to general economic growth in the industrialized countries. Many developing countries, on the other hand, would enjoy considerable comparative cost advantages — because of their vicinity to rich, relatively unexploited fishing grounds — if only existing gaps in technology and know-how were being eliminated. Radical solutions along these lines do not appear feasible at the present time but attempts to move in the right direction through judicious application of aid measures, should not be neglected. In the absence of effective supranational decision-making bodies, it will be the responsibility of the international and bilateral agencies to ensure that resources made available to one country do not create "external diseconomies" for others. To achieve this goal, everybody will have to be educated on the benefits of planning fully integrated investments for large areas.

Unless timely action is taken to harmonize development aid, investments, and fishing effort on a regional basis, the mistakes made and the sorry results produced in such areas as the North Atlantic will be repeated in areas of primary interest to developing countries and everybody will ultimately be a loser.

La planification dans une macro-perspective structurale et géographique — consistant à définir des rapports harmonieux entre les régions, les pays, et les secteurs et unités de l'industrie — devrait précéder la planification à une micro-échelle. L'aide au développement accordée au tiers monde par les pays industrialisés devrait être conçue sur la base d'une répartition internationale de la main-d'oeuvre et d'une distribution des ressources naturelles communes, l'une et l'autre optimales à l'échelle du globe. A partir d'une telle solution d'ensemble, on peut élaborer les solutions optimales aux différents échelons géographiques et sectoriels.

Aménager les pêcheries communes de façon à porter au maximum les revenus économiques nets (c'est-à-dire en fixant des objectifs de production inférieurs au rendement pondéral eumétrique) est une attitude qui peut se concevoir dans les pays industrialisés. Cependant, aussi longtemps que les habitants des pays en voie de développement auront faim et que l'insuffisance de la production alimentaire ne pourra être compensée par des importations, maintenir l'exploitation des ressources halieutiques à un niveau inférieur au rendement maximal équilibré ne semble pas justifiable d'un point de vue global. On ne peut accepter non plus que

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l'efficacité économique maximale soit considérée comme critère absolu pour l'aménagement des pêches, car cela aboutirait sans nul doute à la création d'un monopole virtuel d'exploitation par les pays disposant des techniques les plus perfectionnées, en l'absence d'un dispositif international destiné à garantir que d'autres pays profiteront eux aussi des économies qui en résulteraient.

La formule la plus efficace d'aide au développement pourrait être la redistribution globale de la production et de la transformation du poisson, étant donné que le coût de l'"aide" accordée de cette façon peut être inférieur à celui de l'aide financière et technique mise à disposition par les pays industrialisés. Les "sacrifices" nécessités par cette redistribution des richesses naturelles ne seraient pas énormes, car l'appui accordé à des pêcheries non rentables ou peu rentables n'a souvent été guère plus qu'une entrave à l'essor économique général des pays industrialisés. Par ailleurs, nombre de pays en voie de développement pourraient bénéficier d'avantages considérables en ce qui concerne les coûts comparés — en raison de leur voisinage avec de riches lieux de pêche relativement inexploités — si seulement on pouvait éliminer les lacunes actuelles en matière de technologie et de connaissances techniques. Il ne semble pas possible pour l'instant d'adopter des solutions radicales dans ce sens, mais l'on ne devrait négliger aucun effort pour s'orienter dans la bonne voie par une application judicieuse des mesures d'aide. Faute d'organismes efficaces responsables des décisions au niveau supranational, c'est aux institutions internationales et bilatérales de faire en sorte que les ressources mises à la disposition d'un pays ne créent pas de "diséconomies externes" pour les autres. Pour parvenir à cet objectif, chacun devra être informé des avantages que présente la planification d'investissements pleinement intégrés pour de vastes régions.

A moins d'une action rapide en vue d'harmoniser — sur une base régionale — l'aide au développement, les investissements et l'effort de pêche, les erreurs commises et les résultats regrettables obtenus dans des zones telles que l'Atlantique Nord, risquent de se répéter dans des zones présentant un intérêt primordial pour les pays en voie d'expansion, errements qui seront en fin de compte préjudiciables à tous.

Una planificación integrada en una macroperspectiva estructural y geográfica, y que defina las relaciones deseables entre regiones, países, y sectores y unidades industriales debe preceder a la planificación en pequeña escala. La ayuda de los países industrializados al mundo en desarrollo debe concebirse en función de una división internacional del trabajo y de la distribución de los recursos naturales comunes que parezcan útiles desde el punto de vista global. La solución global constituye un punto de partida para la planificación reducida a escala geográfica y sectorial.

La gestión de los recursos pesqueros de propiedad común para obtener el máximo de ingresos económicos netos (por ejemplo, estableciendo objetivos de rendimiento por debajo del nivel de rendimiento constante máximo) responde a una lógica en los países industrializados. Ahora bien, mientras en los países en desarrollo haya personas que padecen hambre y la producción de recursos alimentarios sea en ellos insuficiente y no pueda compensarse con importaciones, no será justificable a escala global un nivel de explotación de recursos pesqueros que esté por debajo del rendimiento constante máximo. Tampoco la eficiencia económica máxima puede aceptarse como criterio regulador de la gestión, puesto que ello contribuiría sin duda a la creación de un monopolio virtual de la exploración por los países poseedores de las tecnologías más perfeccionadas, a falta de un organismo internacional que garantice que las economías resultantes redundarán también en provecho de otros.

La redistribución global de la producción y elaboración pesqueras podría ser la forma más eficaz de ayuda al desarrollo, ya que el costo de la "ayuda" proporcionada de esta manera podría ser inferior al de la ayuda financiera y técnica facilitada por los países industrializados. Los "sacrificios" que impondría esta redistribución de la riqueza natural no serían grandes, puesto que el apoyo prestado a industrias pesqueras improductivas o marginalmente rentables no ha servido en muchos casos más que para entorpecer el desarrollo económico general de los países industrializados. Muchos países en desarrollo, por otra parte, disfrutarían de considerables ventajas económicas, por estar situados en las proximidades de zonas pesqueras ricas y relativamente poco explotadas, con sólo que se eliminaran las actuales disparidades en materia de tecnología y conocimientos. Por el momento, no parecen realizables las soluciones radicales de este tenor, pero no por ello debe dejar de intentarse avanzar en la dirección debida mediante la aplicación juiciosa de medidas de ayuda. En ausencia de órganos eficaces supranacionales, incumbirá a los organismos internacionales y bilaterales velar por que los recursos puestos a disposición de un país no creen "diseconomías externas" para otros. Para alcanzar este objetivo habrá que instruir a todo el mundo sobre los beneficios que reporta la planificación de inversiones plenamente integradas para zonas importantes.

Si no se toman medidas oportunas para armonizar la ayuda al desarrollo, las inversiones y las actividades pesqueras a escala regional, los errores cometidos y los lamentables resultados consiguientes registrados en regiones como el Atlántico norte se repetirán en otras zonas de interés primordial para los países en desarrollo, lo que, en definitiva, redundará en perjuicio de todo el mundo.

THE theme I have been asked to discuss is that of "development," no stricter definition of this concept being given in advance. Although I shall at some points emphasize certain differences between developing and industrialized countries in employing the development concept and will therefore be touching on development planning in industrialized countries, I intend to concentrate on fisheries development in the developing countries. It is here the main tasks will lie in the next few decades. It will also be clear that I do not consider "development" as a solely quantitative growth, but in an equal degree as an improvement in the use of the resources available at any time. It must be assumed that it is just this type of planning — planning with a qualitative object — that will be most complicated.

Concept of Fisheries Development

What is fisheries development? In ordinary usage, and in much of the fisheries planning that takes place, the usual goals are an increase, over a period of time, in the quantity and value of landed catches, an increase in currency earnings of exports, and in the amount produced by the fish processing industry. Other goals include the development of production equipment, such as the fishing fleet and processing capacity, to a particular size. To what degree are such objectives of any use as development indicators?

Firstly, it must be made clear that growth is not necessarily development. For instance, it cannot be called development if landings increase in excess of the level justified by the natural resources of the region, or if the marginal productivity of the fisheries becomes definitely lower than in an alternative utilization of the resources available. The situation which seems common in certain countries, in which overall catch quotas are combined with an uncontrolled fishing effort, often leads to such a waste of resources. Another example is a disproportionate growth in the part of the industry directed toward export, without a simultaneous growth in the domestic consumption of the country. Fish for export usually demands sophisticated processing on shore, and if increased catches have been obtained by the development of relatively complicated deep-sea fisheries — and this is often the goal — the result will frequently be a switch to capital-intensive operations, with relatively few jobs and heavy requirements with regard to the importation of processing equipment and fishing gear. This reduces the net currency earnings which are the aim of the export effort, and in many cases there is no guarantee that what is being purchased outside is alternative food-stuffs. Various interests will be competing for the use of the increased currency earnings. The fishery industry, as a direct supplier of protein, is in a special conflict situation in countries where such basic needs are still poorly met. A large number of such examples could be listed, cases in which there is reason to discuss in a larger context what "development" means.

The conclusion must be that the concept of development is diffuse, and perhaps without real meaning, as long as development cannot be related to specific goals. What must be sought is a process which will bring the result of productive activities as close as possible to the aims in view. In other words, it is just as much a question of how the economy functions, as of the actual physical level. Within fairly wide limits it is probably correct that (for example) aggregate GNP statistics, taken alone, tell little about the general level of economic welfare in a society. The picture becomes particularly obscure if the production level or growth rate of an individual industry is presented in this fashion. A list of the economic and social priorities, and information on the degree of goal achievement reached in each of these, must supplement purely quantitative information if it is to be possible to make a meaningful statement on the development process in the true meaning of the term.

Development Goals

This brings us to the question of development goals, a question that cannot be disregarded when we speak of industrial planning. A long list of possible objectives, most of which would meet with general agreement, does not come to grips with realities, or throw sufficient light on these questions. It would be more fruitful to discuss who, in reality, should formulate the goals, and to explain their real content and what is necessary for their attainment. Planning has a bearing on all these fields, if by planning one means a charting of those public and private measures which are necessary to guide growth into true development.

I wish to lay particular emphasis on the planning which must take place at a high level, i.e. in a structural and geographical macroperspective. This does not imply any lack of appreciation of the importance of sophisticated and detailed planning in an individual location or in a firm, or of the difficulties involved in this. We must not, however, lose sight of the fact that this is, or should be, the work of trying to fit in the individual piece of the jigsaw puzzle. I wish to concentrate here on the question of what we should put our stake on, how big it should be, and what kind of picture we wish to make. Once this is decided, what remains is largely technical, although certainly complicated. Both planning needs and planning criteria seem, in general, to be already relatively well established, with regard to the planning of the individual catching or processing unit. In my opinion, the greatest need for improvement in quantitative and qualitative planning lies not in the field of project surveys and partial feasibility studies, but on the higher levels, in the structural relation between countries, regions, industrial sectors, and units.

Let us first look at the question of structure in a global perspective. In practice, the possibilities of influencing — not to mention managing — structure on a global plan would be strictly limited, given the present supranational decision-making bodies. It is also obvious that the result of the struggle for resources going on between continents and between countries, and of the competition in joint international markets, may have a great influence on the rate and direction of development in the economy of many developing countries. One can thus say that the general attitude and policy of the industrialized countries with respect to international distribution of resources, and the purely geographical allocation of aid, must be based on well-defined goals for help to developing countries.

If the help given is to be more than a sop to our consciences, it is obvious that questions relating to the international division of labor must be included in development policy in the broadest sense.

We are not concerned only with planning in the usual sense, in that the relevant decision-making bodies are spread over a number of independent governments and international agencies. It is even more to the point to influence the political climate of the relations between developing and industrialized countries. This would require consultations and decisions at a very high level. It should nevertheless be obvious that there is a need for a greater degree of harmonized joint action on a broad international basis, and a few points may be mentioned in this connection.

Relations between Developed and Developing Countries

Our point of departure must be to the relations between the two groups of countries — developed and developing — with the objective of evening out the enormous difference in the economic level of the groups. This objective will affect, among other things, the global distribution of joint natural resources, where the industrialized countries, with their superior technology and superior catching, processing, and marketing know-how, will have to make the first move. As the developing countries naturally enough also compete keenly among themselves in certain fields, not least in the fishery sector, it is also necessary that one of the goals of bilateral and multilateral aid should be to contribute to the management of this competition, insofar as it hinders the growth of the developing countries taken as a group. Such concerted efforts require planning which far exceeds the framework of partial analyses unit by unit, or even region by region. The external effects within the group of developing countries must be taken into consideration in the decisions made by the aid-giving countries, both in general policies such as resource management concepts, and in direct financial help.

An element of such concerted efforts in relation to the developing countries must be a definition of the term "aid" that is wide enough to include public management regarding industrial interests in the aid-giving countries which are in direct conflict with the development efforts of the developing countries. An example of this is the question of the free international exploitation of the fish resources in the third world. It must be assumed that a clarification of principles with regard to the relations between developing and developed countries in such fields would have a considerably greater effect than any further sophistication which may be evolved in detailed planning in the usual sense, important as this is. When an aid organization develops a fishery for the home market in country A, and another organization simultaneously plans a fishery in country B designed to export fish to country A, while the countries that contribute to both organizations have fishing vessels of their own off the coast of both A and B competing for the same resources — then we face a real need for integrated planning. This is the level on which we must start, taking a global total solution as our point of departure, and then suboptimizing down the scale of geographical and sectoral levels.

Such a total approach will provide the first real test of the willingness of the aid-giving countries to make a collective and coordinated sacrifice for the achievement of a joint goal. An important element of this test will be a total reconsideration, and possible alteration, of a number of more or less accepted criteria for what is economically "effective," "rational," etc., within a fisheries development context. It seems possible that the industrialized countries' own interests and patterns of thought have too heavily influenced the content of their existing "philosophy," on which their aid policies are based.

Criteria for Determination of Fishing Efforts

Let us first consider aspects of the present bioeconomic discussion on the value of using the biologically determined "maximum sustainable yield" versus the "economic optimum yield" as a criterion for the determination of fishing efforts. To avoid misunderstanding, it must be emphasized that I do not consider the discussion of purely economic efficiency to be absolutely mistaken or valueless. That the economists have presented their view of the exploitation problem, in addition to that of the biologists who have long held the field, has probably had many favorable effects, with regard to both the regulation of fishing and the sound development of fishing fleets, etc. We must not lose sight of the fact that we are discussing an economically valuable resource.

Nevertheless there is a certain danger that the criteria by which the different optima are fixed will be accepted too easily as valid in a global perspective, although they rest on the thought patterns of industrialized countries, where they were "invented."

The concepts mentioned, or rather the choice among them, really evades the choice among various total levels of the world catch, and therefore, if not in theory then probably in practice, the total world food supply level. Here we find ourselves in the conflict of interests which is detectable in the relations between industrialized and developing countries with regard to development goals in today's situation. For the developing countries, the food supply aspect comes to the fore to cover basic needs that are met almost as a matter of course in the industrialized countries, and that need not be taken into consideration in a way that puts the exploitation of direct food resources in a special position. The economists' use of the optimum concept implies, as far as I understand it, that the "saving" of labor and capital resources achieved by exploiting fish populations so as to give maximum economic profit should be utilized elsewhere and more productively, thereby contributing to a higher economic total result than would be achieved by optimal biological exploitation. For the industrialized countries, considered in isolation, this is a sensible use of resources. The basic requirements which must be met are all fulfilled: the total food production in the area is high enough and at times even too high; there are usually plenty of alternative ways in which to use both capital and labor; there are usually no currency problems in importing other foodstuffs, etc.

In such situations the use of resources can be optimized without regard to the various constraints which exist in a global context. Of course, one might argue that savings in fishing can be used to bring about a higher relative yield in agriculture, or even to produce food artificially, so that the grand total would be higher even if fish that is there for the taking is not caught. However, such alternatives do not necessarily exist and there is at any rate no factual basis on which to ascertain how much fish the world is willing to refrain from catching. In theory this could be determined by the relations between prices and costs by marginal analyses. But what value has free price formation as an indicator of production level in the case of a necessary commodity sold on a market almost without purchase power? Hunger can hardly be explained as a conscious priority in the individual's selection of consumer goods. What we can establish is that a reduction in food production cannot, in a global perspective, be covered through increased imports.

Partial analyses, both geographical and economic, which might result in an optimal exploitation that is lower than the biological basis could support, are questionable in view of this background. There is reason to call for a clearer emphasis on the interests of the third world in the bioeconomic debate now going on, and a definition of the concept of development aid which also includes non-optimal economic solutions on the part of the industrialized countries. An active and concerted policy on the part of the international aid organizations seems imperative.

Maximum Use of Technology in the Fishing Process?

In line with the question of the level of exploitation, we can proceed to one or two other questions whose solutions would affect the global structure of fisheries development. Firstly, we can examine the argument put forward by several industrialized countries to the effect that it is in the interests of all — including the developing countries — that the best available technology be used in the fishing process. This means that those who are able to take the largest catches at the lowest cost are those who are best suited for the exploitation of marine resources. If all economic operations functioned within one system, this "waste-avoiding" theory would be correct, and would have a direct bearing on the global shortage of resources and our joint responsibility for their exploitation. On the other hand, in view of the situation in real life, the technological level of the industrialized countries would, if such an efficiency criterion were employed uncritically, create almost a monopoly. The point is that there is no international mechanism to guarantee that the "surplus" created would flow to others than just those countries which possess the most sophisticated technology. Here again we see that it is the efficiency of distribution as much as of exploitation that is of interest in an overall perspective. It is a fundamental reality that fishery resources are "common property" only as long as they are not caught, while after this point ordinary business principles are of course employed in distribution.

Has anyone hitherto considered thoroughly and without prejudice, the question of whether an alteration in the global distribution of resources might be an effective form of aid to developing countries? Have the individual aid-giving countries done this? Have the aid organizations? If we consider ordinary financial and technical aid in conjunction with the possibility of "giving" natural resources, it is obvious that the fisheries, with their common or non-property nature, represent a possibility. But this would require the drawing-up of basic principles of fisheries development in the developing countries, principles to be based on criteria for a rational global labor division in this field. In this context, "rational" must be taken to mean that form of aid which per money unit (for instance of finances, know-how, or fish) would give the best result in relation to the real goal of development aid, briefly, that of narrowing or bridging the development gap. Although this matter is pregnant with material for political conflict, the only correct point at which to begin must surely be the global planning of resource distribution in which fishery resources are, by their very nature, in a special position.

Global Redistribution of Landings and Processing

The question is both whether global redistribution of landings and processing is effective development aid and, equally, what sources the aid-giving countries can afford to draw on, i.e. for what measures will the actual cost of aid be lowest. This last criterion — what the industrialized countries can afford to give — or are willing to give up — is perhaps the strongest argument for taking a good look at fisheries in the redistribution of wealth which must be the ultimate aim of global planning.

In the fisheries of industrialized countries, both in near and distant waters, an intense technological growth, usually combined with an unregulated fishing effort, has led to economic and biological overexploitation. Regardless of the development goals chosen, development will thus in practice imply a stepwise reduction of fishing effort by these countries. Continued heavy use of subsidies to keep things going at an artificially high level is, in such cases, at cross purposes with a use of resources of both fish and capital that would contribute to a "bridge-the-gap" policy. In the developing countries, on the other hand, resources — especially deep-sea resources — are on the whole poorly exploited or even unexploited, both economically and biologically. This picture of overexploitation where there is a surplus of food, and underexploitation where hunger is a problem, is in itself an indication that another pattern of landings would be rational, even regarded purely from the point of view of costs.

In addition to the differences due to the resource base and to direct food needs, it must be remembered that the economic and social framework of the fishing industry differs widely from country to country. In the industrialized countries it is a general characteristic of the fishing industry, as of all primary industries, that its relative importance for employment and the GNP is decreasing and that it is in various ways being subsidized, either as part of a regional policy or on a purely social basis. If we look at the real costs of fishery activities in the industrialized countries, it seems that a profitable exploitation of resources is to a large extent not achieved. The intensive growth in the productivity of other sectors of the industrial life of these countries has often resulted in the fisheries being a clog on general economic growth.

The developing countries, which have relatively small and weak secondary and tertiary sectors, often combined with a high general level of unemployment, are at a stage of development where a sensible exploitation of resources can form the foundation for a transfer of income from the fishing industry to weaker sectors. In industrialized countries fishing has become a very unattractive way of life in view of the other alternatives which have sprung up. This is reflected in the wage costs of fishing operations and in the very high capital investment necessary to keep the fishing fleet at sea. In the developing countries we have a totally different situation, as long as alternatives are nonexistent or extremely limited. The recruitment problems experienced by the fishing fleets of northern Europe and North America would seem incomprehensible to the developing countries. In a global perspective there is no lack of the labor needed to reap the harvest of the sea. One can of course ask whether it is particularly rational to move men and fleets over very large distances to areas where there is a shortage of labor. However, it is interesting to imagine a situation where the present technological gap and the differences in know-how were ironed out to such an extent that new deep-sea fishing nations were able to grow up. It would then be obvious that the developing countries would be in a very strong position with regard to costs in view of the existing alternative income sources. It would then be extremely difficult to justify fishing operations by the industrialized countries in the vicinity of the coasts of the developing countries, as long as the former subscribed to the ideals of development aid. If such operations were permitted, one would be giving with one hand what one took away with the other.

It seems logical to use the ideal goal of development aid as the yardstick by which international fisheries development and its effect must be measured. In this case a relatively far-reaching change in global structure with regard to fishing effort and landings would have to be a characteristic feature of future international fisheries development; gradually also of large-scale deep-sea fishing. Giving the developing countries a greater expansion potential in this field must of course be linked with the now well-established and indubitable will which the industrialized countries show — at any rate in theory and to some degree also in practice — to transfer resources to the third world, to create growth. An intensified global redistribution of the right and ability to carry on fishing and fish processing would probably be a very suitable measure for furthering this process. Regardless of the vested interests which may exist in the industrialized countries, it is surely generally agreed that such a structural redistribution must be a major element in the concept of fisheries development on a global scale.

Can aid concepts be expanded to include what we might call "the international climate", of which resource distribution forms a part? The answer which springs to mind is that this is purely Utopian. Nevertheless, it should be possible to make a move in the right direction, provided that all central development possibilities are investigated. In the fisheries sector the general attitude to the whole question of resources is probably one of the most important aspects of this matter. As long as individual countries have their own interests to protect — which is only natural — it seems essential that supranational bodies and those national organizations which are responsible for formulating policy with regard to the developing countries be brought in. Planning must surely begin at this end.

Structural Planning

Planning inside the individual country, with certain constraints imposed from without and others from within the national economy, is of particular importance and is certainly complicated enough. However, in spite of the complexity of the problem in real life, it is nevertheless a technical question of economic incentives and management with the goal of optimal solutions for the individual production units. It is difficult to free oneself from the feeling that approaching "development" primarily as a realization of international/global objectives should overshadow these more technical questions at the present stage of world development. It is within this overall framework, set up to such a great degree by the industrialized countries, that the developing countries must exist and develop. It is then worthwhile to devote some time to the framework itself.

More sophisticated planning and more effective management, directed toward a development that fulfils both economic and social goals, are necessary in all countries, irrespective of their level of development. The need for a more economical use of scanty resources makes this vital. The industrialized countries for their part have know-how and trained personnel to put into the domestic development process as the need and the political incentives arise. In view of the relatively limited scope of the fisheries of the industrialized countries today, this can for that matter be largely considered as detail planning within a much broader socioeconomic framework in the individual country. It is the structural development in the relationship of industrialized to developing countries, and developmental management within the developing countries, that must be considered as the real development problems in the time to come, if we take both scope and needs into consideration.

If we maintain that the success or effect of development efforts must be measured by the degree to which goals are attained, and that one of the goals of development aid must be to contribute to a rational international division of labor with the result that the developing countries increase their share of the total landings, then the purpose of aid for planning projects is obvious. Planning will then have as its main objective that of increasing the competitiveness of the developing countries in this sector, with a view to a gradual structural bias favoring third world production. Thus the main purpose of planning is that of promoting a structural change on a global scale in this industry. As long as there are no effective supranational decision-making bodies which can manage such development directly this effect can be attained only by aid measures which influence the relative competitiveness of the individual countries. Let us use the development concept with such a development as the main aim.

Planning within the individual country will then be suboptimizing within a continental framework where, for example, the international aid organizations have a considerable degree of responsibility for seeing that the resources put into one country do not create directly negative effects for another country that also receives help. It is tempting to comment at this stage that the charting of "external diseconomies" on an international scale, on the basis of the individual aid measures, seems in practice to be a neglected area. This is the responsibility of the aid-giving countries and the aid managers. We would probably get closer to these questions by taking a look at certain main problems in the planning now actually being carried on, which must be supplemented with greater efforts on the macrolevel, i.e. through planning for an integrated investment basis for large areas. Harmonization of industrial sectors and individual units is the operative word here.

Approach to Development

In answering the question of "how to approach development" we must take as our point of departure the fact that the goals set up are not necessarily consistent. Partial local planning, perhaps for an individual plant, is by the very nature of its approach unable to tackle the problems that arise.

Conflicting interests arise most directly from two factors. The first is the particular characteristics of the resource base of fisheries. These resources are renewable and the right to them is in principle common as between countries, or as between the fishermen of one country. This has led to the familiar discussion of bioeconomic models and regulation methods. Management on a higher level than that of the individual participants is necessary to give an optimal degree of exploitation. In addition, it is necessary to note that even without regulation of fishing effort total long-term landings will never be able to increase beyond a certain maximum level, regardless of fishing effort. The limits imposed on yield by the natural basis of the fisheries is therefore an absolutely fundamental parameter in all fisheries planning.

A central question in the complex of problems surrounding regulation is — who is to do the fishing, and what techniques are to be employed? Here conflict arises between the interests of different groups of participants and between the different considerations in general economic policy. This becomes especially complicated when several independent countries exploit the same resources and perhaps have widely differing cost and price factors and divergent politico–economic systems to which their industrial life must adapt. Here again there is a need for drawing up a list of priorities, both on a national scale and between the countries involved. Much of the planning which is necessary to achieve maximum development effect must then take place from outside on a supranational basis with an approach within the individual country that makes it possible to harmonize industries and sectors of industry. To put it in another way, the concrete detailed plan for an area or a plant must be incorporated into, and adjusted to, certain frames of reference that are drawn up by macroplanning.

Free international competition for biologically vulnerable resources which can be "imported" without direct currency payments and which cover a primary consumer need, involves strong elements of inefficiency and resource waste, particularly in global perspective. Even inside the limits of the individual country the same dangers will be present but the fact that on the national level there is a single decision-making body, or at least a partly coordinated group of such bodies, can in practice reduce the negative effects to some degree. Let us therefore touch briefly on the coordination problems that exist between countries, considering the developing countries as one group.

Problems of Coordination between Developed and Developing Countries

In the attitude of the aid-giving countries, and wherever else in international policies an attempt is being made to protect the interests of the developing countries, it is essential that individual measures be viewed in a larger context, the external effects of the development process on the resource and market situation in competing countries being taken into consideration. If country A is given support for export development and country B later gets the same for the same market, the overall effect must be questioned in relation to the purpose of the aid given, provided the feasibility of B's project is based on pricing A out of the export market. The same situation may arise on the catching side, especially if the stage of deep-sea fishing expansion has been reached and the competition concerns technological level and fishing effort. It is for that matter not only between countries, but between regions or individual plants within the same country, that such effects arise.

Within the international aid organizations it would be possible to harmonize aid operations with such problems in mind, provided overall plans were worked out as a basis. Bilateral support involves a greater danger here as the contributions from the different countries may well be consciously or unconsciously in conflict with regard to external effects. If we maintain that the combined contributions from the industrialized countries should, ideally, maximize the combined development effect in the developing countries, it may seem that too little attention is paid to the task of plan coordination on the international level with respect to external diseconomies. It is only natural, both in industrialized and developing countries, that the individual nation should disregard the effect of its own measures on competing nations. The responsibility for such considerations — for the rational use of the means transferred — thus lies to a very great extent in the hands of the aid-giving countries.

The expected increase in activity in the fisheries sector, partly financed by development aid, will involve a risk of the same gloomy situation with regard to resources as that existing now in the North Atlantic. The blame for this situation must be laid largely on the lack of international harmonization, on an economic basis, of investments and fishing effort. There should still be a good chance of avoiding the same sad state of affairs in the developing countries, although the situation can, in the main, only be influenced indirectly through well-developed and continuous structural planning and a well-defined use of the development means made available by the industrialized countries. This is a question not only of the allocation of resources within and between the developing countries, but also of the planned coordination of the efforts of the various aid agencies. In the final analysis it will be necessary, both in relations between countries and between conflicting interests within the individual countries, to base the traditional feasibility studies attached to one concrete and isolated project on macroplanning with a much broader economic and geographic approach.

This requirement must as far as possible determine the answer to the question of which development approach should be chosen and particularly of where the decisions should be made. In practice it is obvious that no interests and no national authorities have any desire to give up their decision-making authority to contribute toward a concerted effort that would involve a reduction in their own growth potential, seen in isolation. It must also be remembered that a considerable share of investments is made without help from outside, leaving only indirect means of influence at the international level. These means must consist largely of surveys and concrete planning, with an approach that is partly national and partly multinational.

The goal must be:

(a) to show the external effect to be expected from national investments in relation to the "family" of developing countries; (b) to provide a basis for a purposeful allocation of the national resources through goals-means analyses; and (c) to provide a harmonized basis for a concerted aid and investment policy in the industrialized countries in addition to the partial project studies.

All these subobjectives are interlocked and influence one another. The final goal must be that the investments which are made in planning work should pay their way in the form of more harmonious concerted efforts in purposeful and practical action both by the aid-giving country and the local authorities.

A thorough study of the use of aid funds up to now would, in all probability, show that we are at the present far from this goal. If this is so, as I am convinced it is, it will be necessary to make a close inspection of the allocation principles for development aid and of the planning apparatus. In real life the first problem is formidable, and it is perhaps rather too optimistic to hope for any particular improvement as to concerted effort. In the field of concrete planning, however, there should be more reason to nourish a certain hope, especially with regard to the question of a higher priority to planning on a national basis. This is the planning stage that lies between wide-ranging international or subglobal planning and detailed project planning. There is reason to pay special attention to this planning level because it seems important from the point of view of avoiding negative external effects in the fishery industry, and also because such planning can be initiated by both international and bilateral agencies and by the authorities of the country in question. It also seems a hopeful sign that a concrete demand for this kind of planning already appears to be growing in some developing countries where it is gradually being realized that partial studies as to the feasibility of a plant as such, regardless of their quality, give no guarantee that the industry as a whole will develop in a desirable direction.

Transfer of know-how from the industrialized countries is usually considered in terms of experience gained on the way things should be done. This is important, provided that no attempt is made to copy our forms of operation and management principles too slavishly. But perhaps the most important lesson we should pass on to the developing countries consists of the mistakes made in development of large-scale fishing in industrialized countries. Hopefully the possibility the developing countries have of avoiding our mistakes will strengthen their relative competitiveness in a global perspective.

Lessons from the Expense of Developed Countries

It seems obvious that the lack of total planning and interest for the structural aspects of fishery development lies behind many of the difficulties that mark, for instance, the fisheries of western Europe. In addition to actual problems relating to biological balance, we find a striking lack of harmony between the different links in the production chain, from the resources to the fleet to the processing and to the marketing sectors. In addition we often find a serious lack of coordination between the goals of our fisheries policies — if these are defined at all — and the concrete measures taken. This applies to investment and regulation policies, subsidies, etc.

In countries where the fisheries now make up only a modest part of the total industrial spectrum, such inefficiency need not be taken particularly seriously in considering development in an overall perspective. It would be considerably more serious for coastal states among the developing countries where the fishery industry often is a key factor in the development efforts. Our message to those who now stand on the threshold of fisheries expansion must therefore be: "Learn from our mistakes." It must be the responsibility of the industrialized countries to influence the developing countries to do better than they have been able to do themselves. The key words in this connection must be harmony between the different links in the chain, decision-making within well-defined frames of reference, and goals-means analyses prior to the implementation of public measures or incentives. This would involve a rearrangement of priorities and preferably also an increase in the means available for planning functions. This is the logical first step in the process, whether we call it macro, integrated, or harmonized planning, and it must be given a much higher priority.

In speaking of the grave imbalance in the fishery industries of the industrialized countries I was also thinking of Norway. A fresh example from Norway might throw light on some of the main features of the planning approach that must now be introduced, and which here will come too late to have any deep-reaching effect. The point is that the structural elements here are, in the main, firmly established by the heavy long-term investments already made, both in the fleet and in the processing sector.

My example concerns the fishery industry in north Norway, where fishery development must be seen not only in the usual terms of level of production, cash income, unit by unit feasibility, etc., but also as an integrated part of the regional policy; in other words as a stabilizing factor for the population pattern and population level in the northernmost provinces. In such a situation where it is a matter of minimizing the costs of complying with a regional policy, a "survival of the fittest" way of thinking on a purely commercial basis does not suffice. Similarly, technoeconomic analyses which disregard economic and social external effects will be useless as the first stage of planning. The real problem is that a more or less fixed quantity of raw materials must be caught, distributed, and processed in a manner that will permit the maximum fulfillment of the goals set. The question that must be posed for each ton of fish at our disposal is therefore: "How, where and by whom should this fish be caught, processed and marketed in order to achieve the desired economic and social effects?" This puts us squarely in the middle of the question of fundamental structural principles, with regard to the technological level, scale, and localization of the productive activities. The number, attractiveness, and location pattern of jobs is an underlying planning factor of central importance throughout. Partial preinvestment studies of the usual type will be inadequate in such situations. These belong in the next phase and are then of course of inestimable importance for sound economic development. Nevertheless, we must remember that partial studies concern the individual pieces of the puzzle, and not the picture we are trying to put together.

Conclusions

Regardless of the goals the individual developing country may decide on with regard to the purpose of its fisheries development, it seems clear that a line of thought such as that outlined is necessary if we are to approach the problems before us constructively and with maximum overall efficiency. Both the aid-giving and the aid-receiving countries should make themselves responsible for a critical reconsideration of the planning principles which have hitherto been dominant. Probably the developing countries would do well to learn from our mistakes and the industrialized countries should in the same way be willing to admit that things can be done better now that new countries are beginning operations. Integrated planning would give a high yield if it were implemented by competent personnel.

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Development of Fisheries for Traditionally Exploited Species[1]

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Present catches of traditional marine resources are characterized by a great predominance of pelagic species, especially among the fishes. Since World War II the catch of pelagic fishes has increased by 27.5 million metric tons (mmt) and now constitutes about 70% of the total; production of demersal species has increased by 10.5 mmt. Over 60% of the catch is of plankton-feeding organisms, a little over 25% is predacious fishes, and only 4% bottom feeders.

Of the world catch of aquatic organisms in 1970, 63.4 mmt (90%) was fish, 5.2 mmt invertebrates, about 1 mmt whales, and 0.7 mmt seaweeds. About 90% of this catch was from the ocean. From 1950 to 1970 marine catches rose from 16.1 to 55.8 mmt, while those from fresh waters increased from 2.4 to 7.6 mmt.

About 70% of marine catches are made up of seven families of fishes, with the Engraulidae having by far the leading role — about 24%. Next in order come Clupeidae and Gadidae. Pleuronectidae, Scorpaenidae, Sparidae, etc. are less important. Only 5.06 million tons (8%) of the catch is of invertebrates. Of these 65–70% are molluscs (mostly squids), 30% crustaceans, and 1% echinoderms.

Species such as cod, redfish, rockfish, flounders and clupeids in most areas of the northern hemisphere have reached or almost reached their limit. The greatest increase in demersal catches can be expected from the Falkland–Patagonia area, where landings of hake, poutassou, grenadier, and some other species could reach 3 million tons, and in New Zealand and Australian waters the take may rise to 4 or 5 mmt. Pelagic fishes may eventually yield catches of the order of 17–20 mmt, including sardines, anchovies, mackerels, carangids, sauries, smaller tunas, myctophids, and squids. In all, a future catch of 52 mmt of pelagic species and 30 mmt of demersal species may be possible.

In addition, perhaps 1 mmt can be expected from fishing in depths of 800–1200 m for macrurids, rockfishes, halibuts, etc. The yield of demersal invertebrates may reach 2.2 mmt, anything more would require extensive aquaculture.

A total potential catch of 90 mmt of familiar species is estimated — not including krill, other zooplankton, or seaweed. This figure implies adequate and effective conservation regulations, without which catches can be expected to decline rather than increase.

Les captures des ressources marines traditionnelles sont actuellement caractérisées par la forte prédominance des espèces pélagiques, surtout parmi les poissons. Depuis la deuxième guerre mondiale, les prises de poissons pélagiques ont augmenté de 27,5 millions de tonnes et représentent maintenant environ 70% du total des captures; la production d'espèces démersales s'est accrue de 10,5 millions de tonnes. Plus de 60% des captures sont constituées d'organismes planctonophages, un peu plus de 25% sont des poissons prédateurs et 4% seulement des poissons se nourrissant sur le fond.

Les captures mondiales d'organismes aquatiques faites en 1970 étaient constituées comme suit: 63,4 millions de tonnes (90%) de poissons; 5,2 millions de tonnes d'invertébrés; environ 1 million de tonnes de baleines; et 0,7 million de tonnes d'algues. Ces prises provenaient à 90% environ de l'océan. Entre 1950 et 1970, les captures marines sont passées de 16,1 à 55,8 millions de tonnes, alors que les prises de poissons d'eau douce ont augmenté de 2,4 à 7,6 millions de tonnes.

Environ 70% des captures marines sont constituées de poissons appartenant à sept familles, les engraulidés représentant à eux seuls 24% approximativement. Viennent ensuite les clupéidés et les gadidés. Les pleuronectidés, les scorpénidés, les sparidés, etc. ont une importance moindre. Les invertébrés n'entrent que pour 8% (5,06 millions de tonnes) dans ces prises. De 65 à 70% de ces derniers sont des mollusques (surtout des encornets), 30% des crustacés et 1% des échinodermes.

Dans la plupart des zones de l'hémisphère nord, les captures d' espèces telles que la morue, le sébaste, la morue de roche, le flet et les clupéidés ont quasiment atteint leur limite. La plus importante augmentation des captures de poissons démersaux surviendra sans doute dans la zone des îles Falkland–Patagonie où les mises à terre de merlu, poutassou, grenadier et quelques autres espèces pourraient atteindre 3 millions de tonnes, ainsi que dans les eaux néo-zélandaises et australiennes où elles pourraient parvenir à 4 ou 5 millions de tonnes. Les espèces pélagiques pourraient peut-être fournir des captures de l'ordre de 17 à 20 millions de

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tonnes (sardines, anchois, maquereaux, carangidés, balaous, petits thons, poissons-lampes et encornets). Au total, il serait possible à l'avenir de capturer 52 millions de tonnes d'espèces pélagiques et 30 millions de tonnes d'espèces démersales.

D'autre part, la pêche à des profondeurs de 800 à 1200 m pourrait rapporter 1 million de tonnes de macrouridés, morues de roche, flétans, etc. Les prises d'invertébrés démersaux pourraient atteindre 2,2 millions de tonnes; toute autre augmentation de la production devra résulter d'opérations extensives d'aquiculture.

On estime à 90 millions de tonnes les captures potentielles totales d'espèces traditionnelles — à l'exclusion du krill, des autres formes de zooplancton et des algues. Cela présuppose la mise en oeuvre de règlements adéquats et efficaces en matière de conservation, faute de quoi il faudrait s'attendre non pas à une augmentation mais à une réduction des prises.

Las actuales capturas de los recursos marinos tradicionales están caracterizadas por un gran predominio de las especies pelágicas, especialmente de peces. Desde la Segunda Guerra Mundial, las capturas de peces pelágicos ha aumentado en 27,5 milliones de toneladas métricas, constituyendo actualmente más o menos el 70% del total; la producción de especies demersales ha aumentado en 10,5 milliones de toneladas. Más del 60% de las capturas están compuestas de organismos planktófagos, un poco más del 25% de peces depredadores y sólo el 4% de bentófagos.

En 1970 la proporción de la extracción mundial de organismos acuáticos era como sigue: 63,4 millones de toneladas (90%) de pescado; 5,2 millones de toneladas de invertebrados; aproximadamente un millón de toneladas de ballenas y el 0,7 millones de toneladas de algas marinas. Aproximadamente el 90% de esta extracción procedía del océano. De 1950 a 1970 la extracción marina paso de 16,1 a 55,8 millones de toneladas mientras que la de agua dulce lo hacía de 2,4 a 7,6 millones de toneladas.

Alsededon del 70% de las capturas marinas establa compuesto de siete familias de peces, siendo los engraulidos los que más abundaban, con un 24% aproximadamente. Les siguen los clupeidos y gádidos. Los pleuronéctidos, escorpénidos y espáridos, etc. son menos importantes. Sólo 5,06 millones de toneladas (8%) de las extracciónes son de invertebrados; de estos, de un 65 a un 70% son moluscos (en su mayor parte calamares), un 30% crustáceos y un 1 por ciento equinodermos.

El bacalao, la gallineta, el cabracho, la platija y los clupeidos, en la mayor parte de las zonas del hemisferio norte, han alcanzado su limite de explotación o están a punto de hacerlo. El mayor aumento de capturas de peces demersales es de esperar que se produzca en la zona de Malvinas–Patagonia donde a pesca de merluza, bacaladilla, merluza de cola y otras especies podrían alcanzar los tres millones de toneladas; y en las aguas de Nueva Zelandia y Australia en las cue las capturas podrían alcanzar de 4 a 5 millones de toneladas. Por último, las capturas de peces pelágicos podrían ser el orden de 17 a 20 millones de toneladas, incluídas las sardinas, anchoas, caballas, carángidos, papardas, atunes de menor tamaño, mictópidos y calamares. En conjunto, podría ser posible llegar a pescar 52 millones de toneladas de especies pelágicas y 30 millones de toneladas de especies demersales.

Además, quizás pudiera lograrse un millón de toneladas de macrúridos, cabrachos, hipogloses, etc. pescando en profundidades de 800 a 1200 metros. Los rendimientos de invertebrados demersales pueden alcanzar 2,2 millones de toneladas y para sobrepasar esta cifra sería necessaria una acuicultura extensiva.

Se estima el potencial total de pesca eu 90 millones de toneladas de especies conocides, sin incluir el krill, otro zooplancton o algas marinas. Esta cifra supone una reglamentación eficas para la conservación, sin la cual es de temer que las capturas disminuyan en vez de aumentar.

THE ichthyofauna of fresh and sea waters is extremely varied, comprising some 20,000 species, much more than any group of vertebrate animals.

The highly varied biology of invertebrates, fishes, and cetaceans, the intricate relation between their distribution and environmental conditions, the nature and magnitude of abundance fluctuations under the effect of natural factors and fishing – all these contribute to the difficulties involved in the assessment of the present and potential state of biological and commercial resources.

World Catch

A feature of the composition of the catch of aquatic animals, and especially that of fish, is a great dominance of pelagic animals (Table 1). This predominance of pelagic fishes, cephalopods, and other nectonic organisms results from a higher phyto- and zooplankton production as compared to that of benthos. Since the war the catch of pelagic fishes has increased by 27.5 million tons, mainly due to the development of the Peruvian anchoveta fishery, and this constitutes about 70% of the total world catch; that of demersal fishes has increased by 10.5 million metric tons, accounting for a little over 30%. Some of this increase has no doubt been due to improved hydroacoustic fish-finding equipment and fishing techniques but nevertheless the successful development of pelagic fisheries is determined by the predominance of pelagic resources over bottom-living animals.

This is confirmed by data on the feeding habits of marine fishes in commercial catches (Table 2) (Martinsen 1972). It is seen from this table that over 60% of the total catch of marine fish is accounted for by planktophages, i.e. fish feeding on phyto- and zooplankton; a little over 25% is made up of predatory fish, with small predators predominating; and only 4% are fish-feeding on benthos. Among the planktophagous fish are the more numerous commercial fishes of families Clupeidae, Engraulidae, Scomberesocidae, Carangidae, Scombridae, Scorpaeni-

Table 1. Composition of world catch of marine fish by habitats, in thousands of metric tons.

	1938	1948	1958	1965	1970
Resource	Catch (%)	Catch (%)	Catch (%)	Catch (%)	Catch (%)
Pelagic fishes	9,833 (60.0)	8,773 (56.8)	15,683 (63.1)	28,166 (67.8)	36,200 (67.7)
High-seas areas	900 (5.5)	750 (4.9)	2,500 (10.2)	2,750 (6.6)	2,220 (4.1)
Neritic areas	8,933 (54.5)	8,023 (51.9)	13,183 (52.9)	25,416 (61.2)	33,980 (63.6)
Demersal fishes	6,567 (40.0)	6,697 (43.2)	9,197 (36.9)	13,344 (32.2)	17,280 (32.3)
Shelf areas	6,167 (37.6)	6,097 (39.4)	8,097 (32.5)	11,344 (27.3)	15,107 (28.2)
Slope areas	400 (2.4)	600 (3.8)	1,100 (4.4)	2,000 (4.9)	2,173 (4.1)
Total	16,400(100.0)	15,470(100.0)	24,880(100.0)	41,510(100.0)	53,480(100.0)

Table 2. World catch of marine fishes, classified by feeding habits (millions of metric tons).

	1940	1950	1960	1970
	Catch (%)	Catch (%)	Catch (%)	Catch (%)
Planktophages	8.97 (59)	8.71 (57)	18.10 (62)	36.78 (69)
Phytoplanktophages	0.32 (4)	0.60 (7)	6.12 (34)	14.10 (39)
Zooplanktophages	8.65 (96)	8.11 (93)	11.98 (66)	22.68 (61)
Predators	4.70 (31)	5.13 (34)	8.49 (29)	13.82 (26)
Benthophages	1.15 (8)	1.04 (7)	2.24 (8)	2.52 (4)
Euryphages	0.29 (2)	0.36 (2)	0.38 (1)	0.36 (1)
Total	15.11(100)	15.24(100)	29.21(100)	53.48(100)

dea, etc. The group of benthophages includes Pleuronectidae, Gobiidae, and some other families, and that of predators is composed of sharks, tunas, Xiphiidae, and some others.

The plankton feeders / predators / benthos feeders ratio in terms of weight of the 1970 fish catch is 37:14:2=53. Predacious fish feed mainly on plankton-feeding pelagic fish and to a much lesser degree on benthos eaters, Assuming a food coefficient of 7-8, their consumption of plankton feeders is about 80–90 million tons, and of benthos feeders is about 10 million tons. Hence the total weight of plankton-feeding fish removed by fishing directly and as food of the predacious fishes caught amounts to 120-130 million tons, while that of benthos feeders is about 10–12 million tons.

The productions of zooplankton and benthos suitable as food for fish and other large animals are known to be in the ratio of (13–15 billion tons zooplankton to 1 billion tons benthos. The present catch of plankton eaters (including about 1 million tons of whales and 1 million tons of squids) is estimated to be 10–12 times higher than that of benthos eaters. Hence, some increase in the catch of pelagic planktophages is believed to be possible even if the fishing intensity on demersal fish (benthophages) is at or near its limit. This conclusion seems to be confirmed by the analysis of the volume and the composition of the world catch.

The last 100 years have seen a manyfold increase in the catch of marine and freshwater orgnisms brought about by an ever increasing demand for food and the resulting increase in fishing efficiency (Table 3).

Of the total world catch of aquatic organisms (including whales) in 1970, 63.4 million tons (90%) was fish, 5.2 million tons was accounted for by invertebrates, about 1 million tons by whales, and 0.7 million tons by seaweeds (Table 4).

As seen from Table 5 most of the catch (about 90%) was taken in seas and oceans and consisted largely of typically marine and to a minor extent of anadromous fish as well as of marine inverterates and seaweeds.

Almost the entire increase in the world catch was due to the development of oceanic fisheries. From 1950 (when the world catch again reached its prewar level) to 1970 the catch of marine fish increased from 16.1 to 55.8 million tons, while that of freshwater fish rose only from 2.4 to 7.6 million tons.

Although the marine ichthyofauna consists of a great variety of species, comparatively few of them are fished commercially. Table 7 shows the distribution of the world catch by the main commercial resources.

Table 8 indicates that, despite the intensification of fishing, the catches of many important commercial fishes have declined in the most recent years.

Among the variety of commercial resources only a limited number of species that occur in great abundance and provide large catches determine the level of world fisheries. About 70% of the total marine fish catch is from stocks occurring in the shelf and neritic areas and belonging to seven families — Engraulidae, Clupeidae, Gadidae, Carangidae, Thunnidae, Pleuronectidae and Scombridae. By far the leading role belongs to Engraulidae, whose stocks have provided rapidly increasing

TABLE 3. World catch of fish and other resources (excluding whales) in millions of metric tons.

Year	1850	1900	1913	1930	1938	1950	1960	1965	1970
Catch	1.5–2.0	4.0	9.5	10.0	20.5	20.2	38.0	53.3	69.3

TABLE 4. World catch of aquatic organisms, in millions of metric tons.

	1964	1965	1966	1967	1968	1969	1970
Total	54.80	55.40	58.82	62.35	65.32	63.95	70.33
Fish	48.15	48.69	52.38	55.59	58.37	57.27	63.37
Anadromous and freshwater	7.38	7.88	8.27	8.36	8.55	8.93	9.89
Marine	40.77	40.81	44.11	47.23	49.82	48.34	53.48
Invertebrates and seaweeds	4.75	5.01	5.12	5.51	5.93	5.63	5.93
Whales	1.90	1.70	1.32	1.25	1.02	1.05	1.03

TABLE 5. World catch of marine and anadromous organisms, in millions of metric tons.

	1964	1965	1966	1967	1968	1969	1970
Total	46.19	46.72	50.44	53.90	56.97	55.48	61.72
Fish	41.45	41.71	45.32	48.39	51.04	49.85	55.79
Marine	40.77	40.81	44.11	47.23	49.82	48.34	53.48
Anadromous	0.68	0.90	1.21	1.16	1.22	1.51	2.31
Marine invertebrates and seaweeds	4.74	5.01	5.12	5.51	5.93	5.63	5.93

TABLE 6. World catch in sea and fresh waters, in millions of metric tons.

		Sea waters			Fresh waters		
Year	Total	Total	Marine	Anadromous	Total	Fresh water	Anadromous
1964	52.90	46.20	45.52	0.68	6.70	6.20	0.50
1965	53.70	46.72	45.82	0.90	6.98	6.35	0.63
1966	57.40	50.44	49.18	1.21	7.01	6.40	0.61
1967	61.10	53.90	52.73	1.16	7.19	6.59	0.60
1968	64.30	56.97	55.84	1.22	7.30	6.66	0.64
1969	62.90	55.48	54.00	1.51	7.45	6.82	0.63
1970	69.30	61.72	59.45	2.31	7.62	6.95	0.67

catches in the last 10 years and in 1970 yielded 14.4 million tons, or about 24% of the total world catch of marine fish (Table 9).

ENGRAULIDAE

Within a period of only 10 years (1956–66) the catch of anchoveta along the coasts of Chile and Peru increased 80 times, soaring to 10.5 million tons, since then it has fluctuated near that level. Most of the Japanese anchovies (about 400,000 tons) are caught by Japanese fishermen along the coasts of their country. In the eastern Atlantic, mainly along the northwestern African coast, anchovies are taken by the USSR (130,000 tons, about 30% of the total world catch of this species), by Spain, and by Italy. The research and statistical data available suggest that the catch of anchovies along the Californian and Mexican coasts could be brought up to more than a million tons.

CLUPEIDS

Among the clupeids the species most important commercially are sea herrings, menhaden, and sardines (Table 10).

TABLE 7. Composition of the world catch, in millions of metric tons.

	1964	1965	1966	1967	1968	1969	1970
Total	46.20	46.72	50.44	53.90	56.97	55.48	61.72
Fish	41.45	41.71	45.32	48.39	51.04	49.85	55.79
Engraulidae	10.68	8.81	10.78	11.81	12.54	11.03	14.41
Clupeidae	7.72	8.04	7.95	7.75	7.76	6.93	6.73
Herring	4.29	4.60	4.61	4.30	3.73	2.89	2.80
Gadidae	6.08	6.75	7.29	8.23	9.45	9.80	10.32
Cod	2.79	2.88	2.98	1.24	4.01	3.73	3.26
Alaska pollock	0.92	1.04	1.22	1.74	2.20	2.55	3.06
Hakes	0.82	1.09	1.27	1.67	1.40	1.26	1.42
Other gadoids	1.55	1.74	1.82	1.58	1.84	2.26	2.58
Scombridae	1.02	1.30	1.60	2.25	2.63	2.73	2.79
Thunnidae	1.09	1.11	1.22	1.26	1.32	1.35	1.35
Carangidae	1.30	1.41	1.31	1.28	1.20	1.30	1.59
Pleuronectidae	0.98	0.94	1.09	1.20	1.14	1.25	1.24
Other fish	12.58	13.35	14.08	14.61	15.00	15.45	17.36
Marine invertebrates and seaweeds	4.75	5.01	5.12	5.51	5.93	5.63	5.93

TABLE 8. Changes in the annual increment of the world catch, in millions of metric tons.

	1966	1967	1968	1969	1970
Total	3.72	3.46	3.07	–1.49	6.24
Fish	3.61	3.07	2.65	–1.19	5.94
Engraulidae	1.97	1.03	0.73	–1.51	3.38
Clupeidae	–0.09	–0.20	0.01	–0.83	–0.20
Herring	0.01	–0.31	–0.57	–0.84	–0.09
Gadidae	0.54	0.94	1.22	0.35	0.52
Cod	0.10	0.26	0.77	–0.28	–0.47
Alaska pollack	0.18	0.52	0.46	0.35	0.51
Hakes	0.18	0.40	–0.27	–0.14	0.16
Other gadoids	0.08	–0.24	0.26	0.42	0.32
Scombridae	0.30	0.65	0.38	0.10	0.06
Thunnidae	0.11	0.04	0.06	0.03	0.00
Carangidae	–0.10	–0.03	–0.08	0.10	0.29
Pleuronectidae	0.15	0.11	–0.06	0.11	–0.01
Other fish	0.78	0.53	0.39	0.46	1.90
Marine invertebrates	0.78	0.53	0.39	0.46	1.90
and seaweeds	0.11	0.39	0.42	–0.30	0.30

TABLE 9. World catches of anchovies, in thousands of metric tons.

Stocks	1964	1965	1966	1967	1968	1969	1970
North Atlantic	318	338	331	344	318	244	315
Japanese	342	473	486	456	430	502	430
Argentinian	17	17	11	13	32	16	14
North Pacific	2	3	28	32	14	62	88
Peruvian	9,797	7,681	9,621	10,530	11,272	9,709	13,053
Cape	95	178	160	298	331	397	404
Mexican	23	42	67	61	69	13	33
Other anchovies	86	77	72	79	76	85	82
Total	10,680	8,809	10,776	11,813	12,542	11,028	14,419

In 1970 the catch of clupeids consisted mostly of Atlantic and Pacific herrings (2.8 million tons or 42%); Atlantic herring are more abundant than the Pacific, which form a great number of local stocks and spawn in inshore waters. The abundance of both species fluctuates strongly under the influence of environmental factors and fishing. In recent years most of the Atlantic and Pacific herring stocks have been in a state of deep depression, the catch having declined by 1,800,000 tons (nearly 40%) from 1966 to 1970. There are no reasons to believe that they are likely to be restored to their former abundance in the next 10 years, and moreover that other stocks which are so far in a fairly satisfactory state may not follow a downward trend.

The Atlantic herring supports fisheries in about twenty countries, the highest catches being taken by the USSR (700,000–780,000 tons), Norway (1,200,000 tons), Iceland (770,000 tons) and Denmark (280,000–360,000 tons). Pacific herring are fished mainly by the USSR (320,000–460,000 tons) and Japan (about 100,000 tons), which together take over 90% of the total world catch.

Menhaden occur off the US Atlantic coast and in the Gulf of Mexico. The resource is exploited exclusively by American fishermen and the catch is used for the production of fish meal.

The catches from the stocks of sardines traditionally fished by Portugal, Spain, Morocco, France, Italy, and a number of other countries have not experienced any drastic changes recently (Table 11).

Within the next few years further declines in the pilchard and sardinella catches off the South African coasts, and of Atlantic and Pacific herrings, will lead to a reduction in the catch of fish belonging to this important commercial family, unless the development of fisheries off South America and Australia contribute substantially to the total.

GADIDAE

The third place is occupied by codfishes (10.3 million tons) whose percentage in the total catch has declined somewhat in recent years (from 20–23% to 13–15%) despite an absolute increase, mainly due to higher catches of Alaska pollock, polar cod, saithe, and some hakes (Table 12).

The Atlantic and Pacific cods account for one-third of the total gadoid catch although there has been a sharp decrease in the total cod catch in recent years due to the depression of the Atlantic stock. The Pacific cod catches have somewhat increased. The growth of the total gadoid catch has been due to the development of fisheries in new areas and on previously unexploited stocks, e.g. hakes (Table 13).

However, in spite of high fishing intensity the catches from most of the populations (silver hake, Patagonian, and European hakes) have been declining. The stocks of Pacific and cape hakes are in a good state.

The catch of Alaska pollock, endemic to the Pacific Ocean, has been increasing rapidly, and in 1970 was over 3 million tons, with about 80% of the total taken by Japan. The catches are used for the production of fish meal and minced meat, the latter being used for human consumption. The Alaska pollock stocks in the Korea Bay, Peter the Great Bay, off Hokkaido, Sakhalin, and

TABLE 10. World catch of clupeid fishes, in thousands of metric tons.

Species	1964	1965	1966	1967	19681	969	1970
Sea herrings	4,286	4,600	4,611	4,295	3,734	2,885	2,804
Sardines	2,230	2,190	2,202	2,439	2,851	2,728	2,378
Menhaden	714	784	596	530	625	704	825
Sprats	190	187	216	148	165	199	232
Other	300	279	329	335	383	416	492
Total	7,720	8,040	7,954	7,747	7,758	6,932	6,731

TABLE 11. World catch of sardines, in thousands of metric tons.

Species	1964	1965	1966	1967	1968	1969	1970
Round and flat sardinellas	188	175	187	253	227	381	764
Indian oil sardine	314	334	307	315	369	251	300
Japanese pilchard	16	9	14	17	24	21	17
California pilchard	25	21	19	29	27	30	30
Chilean pilchard	48	50	64	125	95	118	68
South African pilchard	1,067	1,040	952	1,105	1,586	1,402	673
Spanish sardine	42	44	43	42	37	37	41
European pilchard	530	516	616	553	486	488	485
Total	2,230	2,189	2,202	2,439	2,851	2,728	2,378

TABLE 12. World catch of gadoid fishes, in thousands of metric tons.

Species	1964	1965	1966	1967	1968	1969	1970
Cod	2,788	2,880	2,984	3,241	4,010	3,729	3,261
Alaska pollock	918	1,042	1,221	1,735	2,201	2,552	3,057
Haddock	588	748	729	484	487	962	913
Norway pout	110	77	73	198	494	170	309
Poutassou	27	26	27	30	27	37	38
Saithe	403	408	454	420	357	435	598
Polar cod	–	–	1	4	2	134	268
Whiting	169	184	240	187	227	278	228
Tusk	45	44	36	39	38	28	30
Hakes	817	1,085	1,270	1,670	1,396	1,256	1,421
Other gadoids	215	256	255	222	211	219	197
Total	6,080	6,750	7,290	8,230	9,450	9,800	10,320

TABLE 13. World catch of hakes, in thousands of metric tons.

Species	1964	1965	1966	1967	1968	1969	1970
European hake	150	141	135	140	134	129	145
Mauritanian hake	7	11	13	18	14	15	15
Silver hake	321	392	269	127	99	142	222
Patagonian hake	96	102	147	600	183	70	100
North Pacific hake	0	1	134	180	108	172	171
Cape hake	170	332	478	505	712	629	663
Pacific silver hake	73	106	94	100	146	99	105
Total	817	1,085	1,270	1,670	1,396	1,256	1,421

Kamchatka, and in the eastern Bering Sea have been exploited fairly intensively in recent years. It should also be taken into consideration that no less than 10 million tons of Alaska pollock are consumed by fur seals. Already there are indications of a marked decline in the average age of fish in the stock, therefore a further increase in the Alaska pollock catch could be expected only by exploiting new fishing grounds, primarily in the northwestern Bering Sea and the Gulf of Alaska.

An appreciable increase in the gadoid catch may be expected primarily from the development of the hake fishery on the Patagonian shelf and poutassou fisheries in the North and South Atlantic. The catches of cod, haddock, silver hake, and red hake on the established fishing grounds in the North Atlantic are expected to decline, and those of Alaska pollock, cod, and hake in the Pacific are likely to be maintained at about their present levels.

A number of gadoid species, such as whiting (220,000 tons), Norway pout (310,000 tons), tusk (30,000–45,000 tons), and poutassou (20,000–40,000 tons) have so far played a minor role. In most cases the catches do not reflect their true abundance because of the low economic efficiency of these fisheries, which in turn is due to the relatively poor food quality of these species.

SCOMBRIDAE

The expansion of marine fisheries, with the wide use of mid-water trawls, purse seines, long lines, and other efficient gear, has resulted in a rapid increase of catches of a number of pelagic species. Most abundant are the mackerels, whose catch is now 2.8 million tons or 5% of the total catch of marine fish (Table 14).

These species occur in midwater in continental shelf areas and adjoining pelagic areas. A substantial proportion of the catch is taken by Japan (up to 1,400,000 tons), followed by Norway (480,000 tons), with much smaller catches taken by the USSR, France, and South Africa. The spectacular increase of the Norwegian mackerel catch from 23,000 tons in 1963 to 480,000 tons in 1966 is explained by increased abundance of this fish off Norwegian coasts and by the use of purse seines.

Indo-Pacific mackerel are fished by Indian and Thai fishermen in coastal waters. The Soviet Union has recently intensified its mackerel fishery off Japan (up to 80,000 tons) and off West Africa (up to 150,000 tons). Mackerel fisheries hold much promise, especially in some areas of the Atlantic and Pacific Oceans.

CARANGIDAE

The carangid catch by 1970 increased 16 times as compared to 1938 and there is reason to expect further increases. Large jack mackerel concentrations have been recently observed off Tasmania, and many scientists believe that the catch from pelagic stocks around New Zealand (including many carangid species) can be as high as 1 million tons annually.

TABLE 14. World catch of mackerels, in thousands of tons.

Species	1964	1965	1966	1967	1968	1969	1970
Chub mackerel	697	808	772	952	1,312	1,411	1,719
Atlantic mackerel	222	349	664	1,085	1,007	982	700
Indo-Pacific mackerel	100	144	165	214	314	340	368
Total	1,019	1,310	1,601	2,251	2,633	2,733	2,787

TABLE 15. World tuna catch, in thousands of metric tons.

Species	1964	1965	1966	1967	1968	1969	1970
Albacore	184	206	196	224	191	211	203
Bigeye tuna	119	117	116	120	120	131	123
Bluefin tuna	109	102	93	102	100	100	97
Frigate mackerel	35	40	37	39	29	41	46
Skipjack tuna	267	251	324	346	307	293	323
Little tuna	22	29	41	24	36	34	29
Yellowfin tuna	258	255	274	242	331	346	350
Other	97	109	135	162	203	192	180
Total	1,091	1,109	1,216	1,259	1,317	1,348	1,351

The highest quantity of Japanese jack mackerel is caught within the East China Sea and off Japan by the fishermen of this country (510,000–560,000 tons) and around the Philippines. Other carangid species occur off West Africa where they are fished mainly by the Soviet Union (180,000 tons), Angola (170,000 tons), and Spain (70,000 tons).

THUNNIDAE

Tuna fisheries play a minor role, contributing only 1.35 million tons or about 2% of the total catch of marine fish, although due to the high value of tuna meat they are much more valuable than the great majority of fisheries. The market value of tuna in Japan is much higher than that of fish such as saury. Therefore tuna fisheries, although their productivity in terms of weight caught per unit effort is relatively low, have been expanding and already now exploit the resources of the open parts of the Pacific, Atlantic, and Indian oceans. Fishing is complicated by the fact that tuna are relatively sparsely distributed in the open oceanic areas but at the same time this makes them somewhat more resistant to variations in environmental conditions.

The statistical data available for tuna fisheries indicate an unmistakable trend of declining efficiency. The stocks of larger tuna are almost everywhere exploited at high rate and the possibility of developing tuna fisheries can be realized only through the intensification of fishing on smaller tunas such as skipjack. The catch of yellowfin and bigeye tunas, for example, declined from eight fish per hundred longline hooks in 1950 to two in 1965.

The major part of the tuna catch is taken by Japan (50–60%). Much smaller quantities are taken by USA, France, Spain, Peru, and some other countries. The catch of the Soviet Union is only a few thousand tons.

Tuna are fished throughout the year in the Central and South Atlantic, in the Western, Central, and Eastern Indian Ocean, in the Central Pacific from the coasts of Japan, the Philippines and Indonesia to the Pacific coastline of central America, and off the coasts of Australia. The highest proportion of the total tuna catch is taken in the Pacific Ocean (600,000–100,000 tons, or 50–55%), with about 35% (500,000–570,000 tons) caught in the Atlantic and about 10% (170,000–230,000 tons) in the Indian Ocean (Table 16).

Dense tuna schools are fished by purse seines while sparse concentrations are fished by pole and line and by longline using live bait. Catches of specialized longline tuna fisheries include important quantities of Xiphiidae and sharks.

SHARKS, RAYS, AND CHIMAERAS

Sharks and rays are caught in the quantity of 520,000 tons (0.8–0.9%), which does not reflect the state of their stocks. It is believed that the world catch of sharks could be at least doubled.

MISCELLANEOUS DEMERSAL FISHES

The present rate of exploitation of many demersal fishes such as flounders, redfish, rockfishes, etc. is already high enough that no substantial increases in catch are expected. This is shown to some extent by a slow rate of increase in their catches (Table 18).

All the demersal fishes referred to above occur within the limits of the continental plateau or in the upper parts of its slopes and are easily accessible to trawls and other gears. In combination with their long life cycle and low reproductive capacity this distribution has resulted in a rapid depletion of some stocks, especially those of rockfishes and redfishes in the northern areas of the Pacific and Atlantic oceans.

TABLE 16. Distribution of world tuna catch by oceans, in thousands of metric tons.

Ocean	1964	1965	1966	1967	1968	1969	1970
Atlantic	418.9	442.6	420.6	393.6	482.9	516.8	569.6
Indian	122.9	129.5	137.4	179.2	228.4	214.5	167.4
Pacific	549.2	536.9	657.8	686.2	605.7	616.7	614.0
Total	1,091.0	1,109.0	1,215.8	1,259.0	1,317.0	1,348.0	1,351.0

TABLE 17. World catch of sharks, rays, and chimaeras, in thousands of metric tons.

Species	1964	1965	1966	1967	1968	1969	1970
Sharks	212	212	229	244	267	181	281
Rays	117	105	108	117	112	115	125
Chimaeras	3	3	3	3	2	2	2
Unsorted	88	90	100	96	99	112	112
Total	420	410	440	460	480	410	520

TABLE 18. World catch of various demersal fishes, in thousands of metric tons.

Species	1964	1965	1966	1967	1968	1969	1970
Croakers	259	275	283	271	315	256	258
Snappers	228	240	282	288	323	376	384
Sea breams	279	258	288	353	320	251	244
Sandeels	195	254	254	317	356	228	426
Rockfishes	784	945	788	655	570	543	511
Greenlings	221	115	111	86	112	133	174
Others	1,053	1,103	1,224	1,210	1,224	1,313	1,643
Total	3,019	3,190	3,230	3,180	3,220	3,100	3,640

Species of the other families mentioned occur in boreal, subtropical, and tropical coastal areas of the world ocean and support fisheries by many countries.

SAURIES AND CAPELIN

In addition to the above major commercial fishes, which account for the greatest part of the total marine catch, there are some which already make substantial contributions to the catch and are believed to be able to provide increased catches in the immediate future. Among these are the sauries, which are distributed widely over the North Pacific from Japan to California, as well as in the Atlantic. These are believed to be a most promising resource of outer neritic region and the high seas. Another resource offering good possibilities for increased catches is capelin in the Barents Sea and the Northwest Atlantic. In 1970–71 the Norwegian catch of this fish was as large as 1.5 million tons. A recently developed Soviet capelin fishery in the Newfoundland area has been successful. Fairly promising results have been obtained from the fishery for a small pelagic myctophid fish near Japan.

INVERTEBRATES

To conclude this brief review of the composition of the world marine fish catch it should be added that a substantial quantity of commercial fish (9.5 million tons, or 18%) are included in the world catch under the category "unsorted."

The proportion of invertebrate animals in the total world catch of aquatic organisms is far less than that of fish (8% or 5.06 million tons). Of this quantity 65–70% (3.30 million tons) is accounted for by molluscs, about 30% (1.62 million tons) by crustaceans, and a very insignificant quantity (70,000 tons or 1%) by echinoderms. The world catch of invertebrates has been increasing comparatively slowly (Table 19).

MOLLUSCS

The largest catches of molluscs (1.4–1.6 million tons) are taken off Japan (mostly squids, with some bivalves). Fair quantities (0.6–0.7 million tons) are obtained in the United States primarily along the Atlantic coast, with most of the catch consisting of oysters (0.3–0.4 million tons), abalones (0.2 million tons), and scallops (0.1 million tons). The US oyster catch is about half of the world total, with Japan and France sharing most of the other half. Mussels are caught mainly by European fishermen (about 85% of the total), with Holland heading the list (up to 120,000 tons), followed by Spain (70,000), and France (30,000–40,000). Scallops are one of the most valuable

TABLE 19. World catch of invertebrates, in thousands of metric tons.

Species	1938	1948	1958	1961	1965	1970
Molluscs	1,200	1,340	2,070	2,470	2,880	3,300
Crustaceans	600	620	850	980	1,180	1,620
Echinoderms	17	8	34	34	43	70
Total	1,817	1,968	2,954	3,484	4,103	4,990

molluscs; they are caught mostly along the US Atlantic coast by fishermen of Canada (60,000–70,000 tons) and the United States (70,000–80,000). Substantially smaller quantities are taken by Japan and Australia (7,000 tons each).

The prospects of developing mollusc fisheries, primarily for squids but also for small molluscs to be used to feed animals, are favorable in many areas. There seems little doubt that these animals, both from natural habitats and those artificially reared, will find a much wider use.

CRUSTACEANS

Among crustaceans the leading role is played by prawns and shrimps, with the highest catches obtained along the coasts of Mexico, the Atlantic and Gulph coasts of the United States, near Japan, India, and in the Bering Sea. Shrimps and prawns are followed by crabs (mainly king crabs), lobsters, and spiny lobsters. The intensity of exploitation of king crabs and lobsters is such as to require additional measures for regulating catches, although the shrimp, prawn, and spiny lobster resources in a number of areas suggest that some further development of these fisheries is possible.

ECHINODERMS

The exploitation of echinoderms (sea cucumbers, starfishes, sea urchins etc.) is insignificant, the catch being only 70,000 tons, of which about 60% is accounted for by sea urchins used for human consumption in some countries.

SEAWEEDS

The harvest of seaweeds from the shallow waters of the world ocean is very small — only about 0.9 million tons, of which about 70% is taken and cultured off the coasts of Japan.

CETACEANS

As for cetaceans, the rapid depletion of the stocks of larger whales — blue, fin, and humpback — has directed attention in recent years to smaller species, primarily sei and sperm whales. The total weight of the whale catch has been declining from year to year.

Potential Yields

Although in most cases the stocks of traditional resources are already under fairly heavy exploitation, there are many areas in the world ocean where the present level of exploitation could be increased. Calculations made using various methods of estimating fish production from available environmental and fisheries research data, have provided estimates of possible future yields from the fish resources of the world ocean. Estimates were made for different areas separately that could represent the catch that could be obtained with currently used fishing methods acting on traditional commercial resources of fishes and the larger invertebrates. These estimates are based on detailed data on the area and nature of shelf, slope, and pelagic waters, information on the productivity and composition of fish fauna, and on available fisheries statistics. The vast material accumulated by fishery science on the present state of major commercial stocks and the extent of their exploitation, as well as the existing knowledge of the basic patterns of their behavior, distribution, and abundance, provide a basis for a reasonably reliable estimate of the possible future fish production of the ocean.

The analysis of Table 20 shows that the intensity of exploitation of many important commercial fishes such as most codfishes, redfishes, rockfishes, flounders, and clupeids in the majority of areas of the northern hemisphere has reached or almost reached its limit, and that increased catches from these resources could be obtained only as a consequence of increases in the abundance of individual year-classes owing to some favorable environmental events. This applies primarily to the Northwest and Northeast Atlantic, and to the Northern and Western Central Pacific. In these regions increased catches can be expected of demersal fishes such as grenadiers on the upper part of the continental slope, and Alaska pollock, polar cod, and Pacific cod in some areas of the Atlantic and Pacific oceans. However, the increases are likely to be relatively small and would not to any large extent offset the decline in the yield of fisheries in the most important fishing areas.

The greatest increase in demersal catches can be expected in the extensive Falkland–Patagonia shallow area where the yield of hake, poutassou, grenadiers, and certain other demersal species can probably become as great as 3 million tons. Not nearly so large but still considerable possibilities of increasing demersal catches exist in the shallow areas around New Zealand and off the east and south coasts of Australia. Other areas of the world ocean will probably yield only insignificant increases over the present level. Thus, the total possible increase of demersal catches in shallow waters is estimated to be 4–5 million tons, with most of it coming from the two regions referred to above.

A much larger increase (of the order of 17–20 million tons) can be expected in the yield of fish and other animals that live pelagically, feed on plankton, and inhabit fairly productive neritic regions which form zones up to several hundred miles wide adjoining the coasts of continents, islands, and insular arcs. These are first of all sardines and

TABLE 20. Present (1970) and potential yields of the world ocean resources.

Region	Area (million km²)		Catch (million tons)			Present and potential production (kg/km²)				Potential catch	Potential increase
	Total	Shelf and upper slope	Total	Demersal	Pelagic	Total	Shelf (demersal resources)	Coastal-pelagic waters (pelagic resources)	Open oceanic waters (pelagic resources)	(million tons)	(million tons)
Atlantic Ocean	93.4	13.6	23.6	12.3	11.3	240/360	900/1100	330/500	9/20	33.7	10.1
Northwest	4.0	1.5	4.2	3.7	0.5	1050/1200	2300/2300	120/250	–	4.8	0.6
Northeast	7.0	4.4	10.7	6.2	4.5	1550/1650	1400/1400	650/750	–	11.5	0.8
Mediterranean and Black Sea	2.9	0.9	1.2	0.2	1.0	400/510	150/510	300/330	–	1.5	0.3
Western Central	7.4	1.8	1.5	0.4	1.1	85/200	200/500	150/310	–	3.4	1.9
Eastern Central	15.0	0.9	2.6	0.4	2.2	180/200	400/500	520/600	–	2.8	0.2
Southeast	19.2	0.4	2.4	0.9	1.5	130/200	1250/1700	2100/3800	–	3.9	1.5
Southwest	21.0	2.6	1.0	0.5	0.5	50/270	300/1400	50/260	–	5.8	4.8
Indian Ocean	74.9	6.4	2.8	1.6	1.2	30/70	250/350	70/240	4/10	5.3	2.5
Western	36.6	2.7	1.7	0.9	0.8	30/60	260/350	110/250	–	3.2	1.5
Eastern	29.9	1.9	1.1	0.7	0.4	30/70	300/350	70/200	–	2.1	1.0
Pacific Ocean	178.9	15.5	35.3	12.8	22.5	190/230	900/1000	580/800	6/15	42.6	7.3
North	11.2	3.2	8.2	5.2	3.0	720/800	1550/1600	330/460	–	8.9	0.7
Western Central	48.3	5.9	12.3	7.0	5.3	230/260	1200/1250	500/530	–	12.4	0.1
Eastern Central	32.8	0.6	0.9	0.2	0.7	250/950	300/500	350/1200	–	3.1	2.2
Southwest	49.3	1.6	0.2	0.1	0.1	40/300	60/300	120/300	–	1.6	1.4
Southeast	22.8	0.6	13.7	0.3	13.4	600/630	500/1000	7200/7000	–	14.1	0.6
World Ocean	360.2	41.8	61.7	26.7	35.0	170/230	630/820	330/550	7/17	81.6	19.9

related species, anchovies, mackerels, carangids, sauries, smaller tunas, myctophids, squids, and some others. Judging from the level of exploitation of these resources that has been achieved in the neritic regions of some oceanic areas, and considering the data on their distribution and abundance, a substantial increase in their catches can be expected in all areas of all oceans, but primarily off the coasts of Australia, in the North, Western Central, and Eastern Central Pacific, and in the Southwest Atlantic. Less promise is shown by central oceanic areas because generally these are regions of low productivity. Low abundance is typical of animals of the open ocean and moreover commercially important species inhabiting these areas are largely predators, i.e. animals of the fourth, fifth, or even sixth trophic level. Even a threefold increase of catch in these areas, which would by no means come very easily owing to the present reduction of the main commercial high seas stocks (larger tunas and Xiphiidae) by fishing, would hardly bring up the catch to over 5 million tons.

The state of the living resources of the world ocean suggests the very rough estimates of possible increases in the world catch of marine fishes shown in Table 21.

In the majority of areas the most likely contributors to increased catches are fishes living over the upper part of the continental slopes, such as grenadiers, hakes and poutassou, and in the warmwater shelf areas the numerous species of carangids, sciaenids, and some others. Much smaller contributions may be made by saithe, haddock, Alaska pollock, and cod. A fairly substantial increase in the total catch may be provided by alfoncino, snoek, and some other fishes from the waters around Australia. In the neritic zone the greatest prospect for the development of fisheries is offered by anchovies, sauries, mackerels, jackmackerels, sardines, smaller tunas,

TABLE 21. Potential increase in the yield of marine resources, in millions of metric tons.

Group of animals	1966 catch	1970 catch	Potential increase in catch	Potential catch
Pelagic resources	31.3	35.0	16.6	51.6
Engraulidae	10.7	14.4	2.6	17.0
Clupeidae	7.9	6.7	2.3	9.0
Carangidae	1.4	1.6	2.0	3.6
Scombridae	1.7	2.8	0.5	3.3
Scomberesocidae	0.3	0.3	2.2	2.5
Thunnidae	1.3	1.4	1.4	2.8
Sharks	0.2	0.3	0.6	0.9
Squids	0.7	0.9	3.1	4.0
Other pelagic	7.1	6.6	1.9	8.5
Demersal resources	18.8	26.7	3.3	30.0
Gadidae	7.3	10.3	0.3	10.6
Pleuronectidae	1.1	1.2	0.0	1.2
Macruridae	0.1	0.3	0.7	1.0
Other demersal	10.3	14.9	2.3	17.2

myctophids, squids, and some other species. And finally in the oceanic zone proper, usually called the high seas or the "open ocean," the principal resources to support developing fisheries are the larger and smaller tunas, marlins, swordfishes, dolphinfishes, sauries, sharks, flyingfishes, and squids.

It can, therefore, be said with a fair degree of confidence that world fisheries are likely to develop primarily through the exploitation of additional pelagic resources.

Though some species of anchovies are already under extremely heavy exploitation it is believed to be possible to intensify anchovy fisheries along the coasts of Argentina, Mexico, and in some other areas, which could yield about 3 million tons. Considering that the abundance of anchovies is subject to substantial fluctuations, large drops in catches are possible, as in the case of the Peruvian anchoveta and some other short-lived species.

It is highly probable that increases could be made in the catches of sardines and related forms occurring off the West African coast, and particularly in the waters around Australia, as well as some scombrids and carangids in various areas. There is evidence suggesting the existence of many sauries in the open oceanic and neritic regions of the Pacific and Atlantic oceans, among which the North Pacific saury are believed to be the more numerous. Subject to the development of efficient methods of artificially concentrating sauries in open areas this fish may become an important commercial resource.

A substantial increase in catches may be expected through the development of fisheries on the stocks of smaller tunas, which are underexploited in many areas. There are no reasons to expect any appreciable increase in the catches of larger tunas, whose stocks in all three oceans have clearly been affected by fishing.

The present catch of sharks could probably be doubled, but in general this fishery cannot be expected to become really large because most sharks are predators, i.e. animals at the fifth or even sixth trophic level.

Squids are undoubtedly a promising resource of the pelagic waters, with stocks capable of supporting a catch many times higher than at present. Among the "other" pelagic fishes are capelin, flyingfishes, Australian salmon, dolphinfish, myctophids, and many others. Intensification of exploitation of pelagic resources, primarily through the development of fisheries in new areas, is expected to increase the catch from these resources by 20 million tons.

Thus pelagic resources are the principal source of a potential increase in the total world catch; demersal resources will play a minor role, subject to the development of their fisheries in new areas. In most heavily exploited areas the stocks of cods, rockfishes, redfishes, flounders, halibuts, and many other demersal species are not likely to make substantial contributions to the increased catch, and their fisheries are in need of severe regulatory measures. A fairly large increase in the world catch (up to 1 million tons) might be expected from the development of fisheries over the upper part of the continental slope, down to the depths of 800–1200 m. This region is inhabited by various macrurids and by certain species of rockfishes, halibuts and some other fishes. Included in the category of demersal resources are bottom invertebrates, whose catch is not likely to be increased (without active participation of man in their reproduction) by more than 2.2 million tons.

The analysis of possible increases in catches from different oceans shows that the Atlantic and Pacific oceans offer the greater promise (Table 22).

These figures do not include marine mamals (whales, seals, fur seals etc.), whose catch today is 1–2 million tons, and is likely to decline in the immediate future.

Thus, the potential catch of fish, large invertebrates, and marine mammals is estimated (subject to possible errors) to be of the order of about 90 million tons.

The figures given above do not include resources such as krill or any other zooplankton forms, or seaweeds. We have also disregarded the possibility of increasing the productivity of various areas by acclimatization or transplantation of fish or forage organisms, by fish culture, or by human activities aimed at making environmental conditions more favorable for fish reproduction, etc.

The figures given in this paper refer to traditional resources of fish and large invertebrates, and should be regarded as an attempt at a first approximation to the estimate of the possible volume and composition of catch from the world ocean, based on the assumption that fishing will continue as a form of hunting which, though conducted in accordance with the necessary rules, is nevertheless dependent only on what is produced as a natural "harvest." At the same time they imply adequately effective fishery regulations based on the state of stocks and the nature of populations. Failing this, the present fishing intensity may lead to an irreparable damage to various populations, decreases in catch, and an overall decrease in the potential of the ocean.

TABLE 22. Possible increase in catch from the world ocean, in millions of metric tons, as compared with 1970.

Ocean	Demersal		Neritic–pelagic		High–seas		Total		
	Present	Possible	Present	Possible	Present	Possible	Present	Possible	Increase
Atlantic	12.3	15.5	10.9	17.2	0.4	1.0	23.6	33.7	10.1
Pacific	11.1	13.0	23.0	26.8	1.2	2.8	35.3	42.6	7.3
Indian	1.6	2.2	0.8	2.3	0.4	5.3	2.8	8.5	5.3
World	26.7	30.0	33.0	47.0	2.0	4.6	61.7	81.6	19.9

Development of Fisheries for Nonconventional Species[1]

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Suda, A. 1973. Development of fisheries for nonconventional species. J. Fish. Res. Board Can. 30: 2121–2158.

Estimated possible increases in world catch are 21.9–29.7 million tons of pelagic fish, 15.5–18.6 million tons of demersal fish, and 5.7–7.0 million tons of cephalopods, a total of 43.55 million tons. This is on the assumption that such a rate of exploitation would not adversely affect other fish resources. The potential may be a bit higher because certain resources for which assessments are lacking have not been included. There may also be local stocks which have not been included. The average actual catch of fish and cephalopods combined, in recent years, has been 50–55 million tons. Added to the possible increase, this gives 93–110 million tons as the estimated total potential yield.

The major part of the potential increase is of small-sized species at low trophic levels. These will be utilized largely for reduction, with little for direct consumption as human food. The more abundant resources in this category are lampfishes, lightfishes, and flyingfishes. Fish of the highest quality as food are already being heavily exploited. Underexploited species potentially usable as food include rainbow runner, dolphinfish, small tunas, notothenids, boarfish, berycoid fishes, and squids, also miscellaneous local species including snappers, groupers, butterfish, and croakers. Nonconventional resources of both types are mostly in distant waters, and each presents technical difficulties in exploitation.

Making a bold assumption that the possible increase in catch of food fish is five times that of the estimated possible catch of skipjack and boarfish combined, we get 6,500,000 tons of preferred species. If we also presume that 50% of the potential increase in the catch of horsemackerel, mackerel, herring, hake, and poutassou is consumed directly, the possible increase in the supply of food fish will be as follows: Directly edible species, 6,500,000 tons; Horsemackerel and mackerels, 1,600,000 tons; Hake and poutassou, 1,100,000 tons; Herring, 500,000 tons; Total, 10,000,000 tons. The ratio of directly edible fish to the total potential increase in catch is therefore about 20%.

A possible distribution of the total additional catch is as follows (in millions of tons):

Oceans	Pelagic fish	Demersal fish	Cephalopods	Total
Northern	4.2– 5.7	1.8	1.7	7.7– 9.2
Southern	6.8	1.8– 2.3	1.8	10.4–10.9
Tropical	10.9–17.2	11.9–14.5	2.2–3.5	25.0–35.2
Total	21.9–29.7	15.5–18.6	5.7–7.0	43.1–55.3

Selon les évaluations, il serait possible d'augmenter les captures mondiales de quelque 21,9 à 29,7 millions de tonnes de poissons pélagiques, de 15,5 à 18,6 millions de tonnes de poissons démersaux et de 5,7 à 7,0 millions de céphalopodes, soit au total un accroissement de 43,55 millions de tonnes de poisson. On présume qu'un tel taux d'exploitation n'aurait pas d'effet contraire sur les autres ressources en poissons. Il se peut que le potentiel soit un peu plus élevé, car on n'a pas inclus dans cette énumération certaines ressources pour lesquelles on n'a pas d'évaluation. Il se peut aussi que l'on n'ait pas tenu compte de certains stocks locaux. En moyenne, les captures globales de poissons et de céphalopodes lors des dernières années ont été de 50 à 55 millions de tonnes ce qui, si l'on ajoute à ce chiffre l'accroissement possible, donne une estimation de 93 à 110 millions de tonnes comme rendement potentiel total.

L'accroissement potentiel est surtout constitué par des espèces de petite taille occupant de bas niveaux trophiques. Ces espèces seront largement utilisées aux fins de réduction, et très peu pour la consommation directe dans l'alimentation humaine. Dans cette catégorie, les ressources les plus abondantes sont représentées par les poissons-lampes, les poissons lumineux, et les poissons volants. Les poissons de la plus haute qualité alimentaire sont déjà fortement exploités. Les espèces sous-exploitées et potentiellement utilisables comme aliments comprennent la carangue arc-en-ciel, les coryphènes, les petits thons, les notothénidés, le sanglier de mer, les bérycidés et les encornets, ainsi que diverses espèces locales parmi lesquelles les

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

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lutianidés, les mérous, les stromatées et les grondeurs. Les ressources non traditionnelles des deux types sont généralement situées dans les eaux lointaines et leur exploitation présente des difficultés techniques.

En supposant, hypothèse hardie, que l'accroissement possible des captures de poissons comestibles représente cinq fois le chiffre global des captures de bonites à ventre rayé et de sanglier de mer, qu'il est possible de réaliser selon les estimations, nous obtenons au total 6,500,000 tonnes de poisson appartenant aux espèces de choix. Si nous supposons également que 50% de l'accroissement potentiel des captures de chinchards, de maquereaux, de harengs, de merlus et de poutassous est consommé directement, l'accroissement possible des approvisionnements de poisson destiné à la consommation humaine sera le suivant: Espèces directement comestibles, 6,500,000 tonnes; Chinchards et maquereaux, 1,600,000 tonnes; Merlu et poutassou, 1,100,000 tonnes; Hareng, 500,000 tonnes; Total, 10,000,000 tonnes; Le pourcentage de poisson directement comestible sur l'accroissement potentiel total des captures est donc d'environ 20%.

On trouvera ci-après une distribution possible du total des captures supplémentaires:

Océans	Poissons pélagiques	Poissons démersaux	Céphalopodes	Total
Nord	4,2- 5,7	1,8	1,7	7,7- 9,2
Sud	6,8	1,8- 2,3	1,8	10,4-10,9
Tropical	10,9-17,2	11,9-14,5	2,2-3,5	25,0-35,2
Total	21,9-29,7	15,5-18,6	5,7-7,0	43,1-55,3

Se calcula que las capturas mundiales de peces pelágicos podrían aumentar entre 21,9 y 29,7 millones de toneladas, las de peces demersales entre 15,5 y 18,6 millones de toneladas, y las de cefalópodos entre 5,7 y 7,0 millones de toneladas, con un total de 43,55 millones de toneladas. Naturalmente, suponiendo que este ritmo de explotación no influya negativamente en otros recursos pesqueros. Tal vez las posibilidades sean algo mayores, porque algunos recursos sobre los que no se dispone de evaluaciones no se han incluido en los cálculos. Puede suceder también que algunas poblaciones hayan quedado excluidas. La captura media de peces y cefalópodos en los últimos años ha sido de 50–55 millones de toneladas, cifra que, añadida al aumento posible, arroja un rendimiento potencial total que oscila entre 93 y 110 millones de toneladas.

La mayor parte de este aumento potencial se refiere a especies de pequeña talla y niveles tróficos bajos, que se utilizarán en buena parte para reducción, aprovechándose apenas para el consumo humano directo. Los recursos más abundantes de esta categoría son los peces linterna, los gonostómidos y los peces voladores. Los peces de mejor calidad para el consumo se explotan ya intensamente. Entre las especies subexplotadas que podrían utilizarse como alimento figuran la arabaiana, la lampuga, los túnidos de pequeña talla, los nototénidos, el ochavo, los berícidos y los calamares, además de algunas especies locales como pargos, chernas, pámpanos y corvinas. Los recursos no aprovechados de ambos tipos se encuentran en su mayor parte en aguas distantes y la explotación de cada uno de ellos plantea dificultades técnicas específicas.

Suponiendo que el aumento posible de la pesca para el consumo sea cinco veces superior al de la captura posible estimada de listado y ochavo juntos, obtenemos un total de 6,500,000 toneladas de las especies preferidas. Si suponemos, además, que el 50% del aumento potencial de las capturas de jurel, caballa, arenque, merluza y bacaladilla se consume directamente, el posible aumento del abastecimiento de pescado para el consumo será el siguiente: Especies directamente comestibles, 6,500,000 toneladas; Jurel y caballa, 1,600,000 toneladas; Merluza y bacaladilla, 1,100,000 toneladas; Arenque, 500,000 toneladas; Total, 10,000,000 toneladas. El porcentaje del pescado directamente comestible respecto al aumento potencial de las capturas es, pues, de un 20%.

Las capturas adicionales totales podrían distribuirse como sigue:

Océanos	Peces pelágicos	Peces demersales	Cefalópodos	Total
Norte	4,2- 5,7	1,8	1,7	7,7- 9,2
Sur	6,8	1,8- 2,3	1,8	10,4-10,9
Tropical	10,9-17,2	11,9-14,5	2,2-3,5	25,0-35,2
Total	21,9-29,7	15,5-18,6	5,7-7,0	43,1-55,3

Kinds of Resources

SCHAEFER and Alverson (1968) reviewed various estimates of the possible yield of marine animals (Table 1). There are two types of forecasts, one based on extrapolation from the present catch, the other on analyses of the theoretical flow of organic material through the food chain at different trophic levels. The latter estimates tend to be the higher, partly because they include all marine animals of suitable size, but because some kinds of

animals are not likely to be utilized by man such estimates seem overly optimistic. Moreover, such estimates do not identify the species of animals that will be used in future, where they occur, or the kind of fishing techniques that are needed to harvest them. In an attempt to clarify the situation, in this paper a study has been made of reports covering: (1) records of by-product species taken in conventional commercial fisheries; (2) records of experimental fishing; (3) the stomach contents of commercially utilized species; (4) samples of fish larvae taken in coarse-meshed plankton nets ("larval net"); (5) observations by scientists at sea.

To develop estimates of the utilization of new resources their biological characteristics have been reviewed, including horizontal and vertical distribution, life histories, behavior, and biological parameters required for the development of population dynamics.

The survey is restricted to fishes and cephalopods, since insufficient information is available concerning shelled molluscs, crustaceans, and other kinds of animals.

The following members of the staff of the Far Seas Fisheries Research Laboratory have collaborated in the preparation of this paper: Drs S. Hayasi (pelagic fishes), H. Ikeda (demersal fishes), Kikawa (pelagic fishes), K. Nasu (oceanography), T. Takahashi (demersal fishes), and S. Ueyanagi (pelagic fishes).

The estimates given of the potential increase in catch are based mainly on "The Fish Resources of the Ocean" (Gulland 1972). Assistance has also been received from Dr F. Nagasaki of the Far Seas Fisheries Research Laboratory.

The "nonconventional resources" treated in this paper are those from which the potential catch is expected to exceed several tens of thousands of tons. Such resources fall into four main divisions.

Coastal Pelagic Fishes

Many species in this group have already been heavily exploited, largely because they are located close to land. But there are still some which are underexploited because of some kind of economic handicap. Many of them are carnivores at lower trophic levels. Their occurrence is related to high primary productivity. Some stocks of clupeoid fishes (herring, sardines, and anchovies), and of horsemackerels, scads, and true mackerels are still underutilized.

Oceanic Pelagic Fishes

These resources are distributed widely over the high seas and, apart from the larger tunas, only a small part of them are being fully utilized. Underutilized stocks in this group include flyingfishes, sauries, rainbow runners, dolphinfishes, and the small tunas (skipjack, black skipjack, blackfin, longtail tuna, frigate mackerels, slender tuna, and bonitos).

Oceanic Mesopelagic Fishes

Fishes of this group have not been exploited because they live in deep offshore waters and individually are small in size. The potentially important fishes of this group are lanternfishes (myctophids) and gonostomatids.

Demersal Fishes

It is convenient to consider four groups under this heading: The first of these includes fish that are caught on conventional fishing grounds along with traditionally marketable species, and are largely a by-product of existing operations; they include the capelin, sand lance, and argentines. These species are usually at a lower

TABLE 1. Estimates of total yields of marine animals, from Schaefer and Alverson (1968). (ext=extrapolation from catches; f=flow of organic material through the food chain.)

Author	Forecast (million metric tons)	Year	Method
Thompson	21.6	1949	ext
FAO	55.4	1955	ext
Finn	50–60	1960	ext
Graham and Edwards	55 (bony fishes)	1962	ext
Meseck	55 (by 1970)	1962	ext
Graham and Edwards	60 (bony fishes)	1962	ext
Schaefer	66 (by 1970)	1965	ext
Meseck	70 (by 1980)	1962	ext
Alverson	80	1965	ext
Bogdanov	70–80	1965	ext, f
Graham and Edwards	115 (bony fishes)	1962	f
Schaefer	160	1965	ext
Schaefer	200	1965	f
Pike and Spilhaus	200	1965	f
Chapman	1000	1966	f
Pike and Spilhaus	180–1400	1962	f
Chapman	2000	1965	f

trophic level than the more highly esteemed species. The second group constitutes the resources on the slope of the continental shelf in temperate waters, where modern fisheries are less developed. These include such fishes as hake, poutassou, macrurids, morids, and notothenids. The third group, the resources found on the tropical continental shelves, comprise a wide variety of species for which there is at present a limited demand. The fourth underexploited group is found on oceanic ridges and guyots. It includes the boarfish and berycoid fishes in the temperate zones, a variety of species in the tropical zones, and cephalopods everywhere.

The occurrence of fishes, especially those at lower trophic levels, is significantly related to the occurrence of zooplankton. In turn, concentrations of zooplankton are found where there are upwellings, influx of water from the land, turbulence near islands, convection of water in high latitudes (45–50°N and S) and the upward movement of deep water along the slopes of continental shelves. The distribution of zooplankton is shown in Fig. 1, of phosphatic deposits in Fig. 2 and of guano islands in Fig. 3. Major upwelling areas and their productivities are listed in Table 2.

Biological information on substantially exploited resources such as herring, sardines, mackerel, and hakes is readily available, so that only information on their fisheries and size of catches is given in this paper.

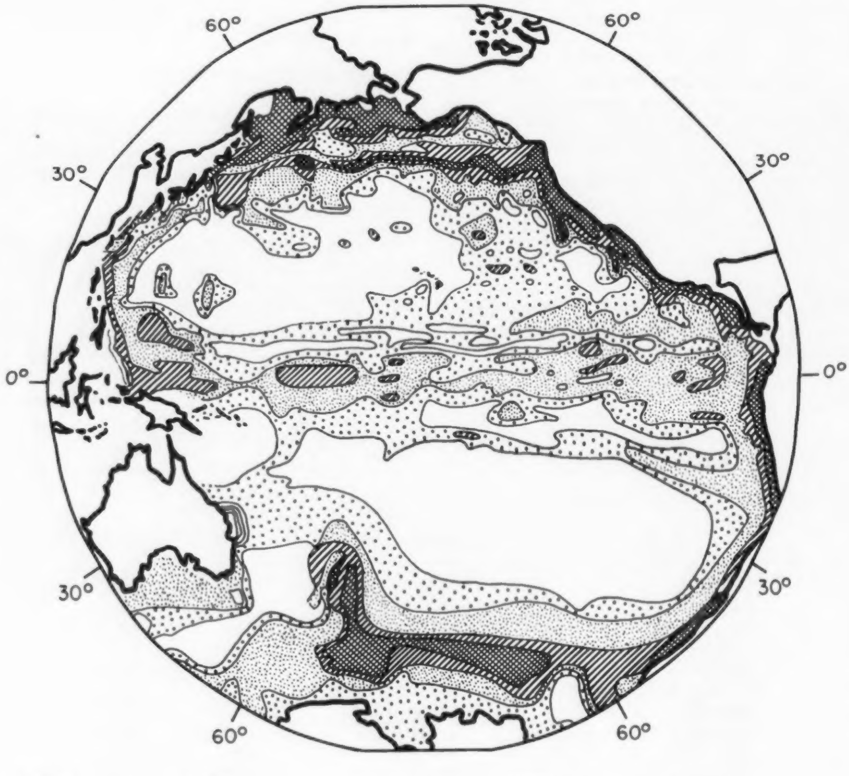

FIG. 1. Distribution of zooplankton in the upper layers of the Pacific, in ml/1000 m^3 displacement volume (adapted from Reid 1962).

Coastal Pelagic Fishes

Clupeoid fishes (herring, sardines and anchovies) are first-level carnivores, hence occupy the third trophic level of the food pyramid.

COLD-WATER CLUPEOIDS

Cold-water species, such as herring and sprats, occur on the continental shelf where the mixing of coastal and arctic or subantarctic waters takes place. The major stocks are listed in Table 3. Of these, the Atlantic and Pacific herrings and sprats are already intensively harvested. The Falkland herring is the only latent resource among these. It appears to be abundant from southern Chile to the southernmost point of South America; in the Atlantic it extends as far north as Golfo San Jorge, and in the Pacific to about 35° S. Detailed information on the biology of this species is not available, but assuming a distribution similar to that of the Atlantic herring, the possible catch is estimated at 1 million tons.

TEMPERATE AND SUBTROPICAL CLUPEOIDS

The locations of major clupeoid stocks in temperate and subtropical waters are given in Table 4. No substantial increase in catch can be expected from any stock of sardines or pilchards, but there are potentialities for catching more anchovies and *Sardinella*, even in the northern hemisphere.

TROPICAL CLUPEOIDS

There are many local stocks of tropical clupeoids, although the true sardine or pilchard (*Sardina pilchardus*) scarcely enters this region. The information available suggests a large potential catch (Table 5). Small-sized clupeoids are used as live bait in fishing for tunas, skipjack, and Spanish mackerel. However, they do not live long in the live bait tank (Far Seas Fish. Res. Lab. 1970). Although these tropical species have been considered as coastal, Ueyanagi et al. (1969) found larvae of *Storephores buccaneri* distributed over wide offshore areas of the western tropical Pacific (Fig. 4).

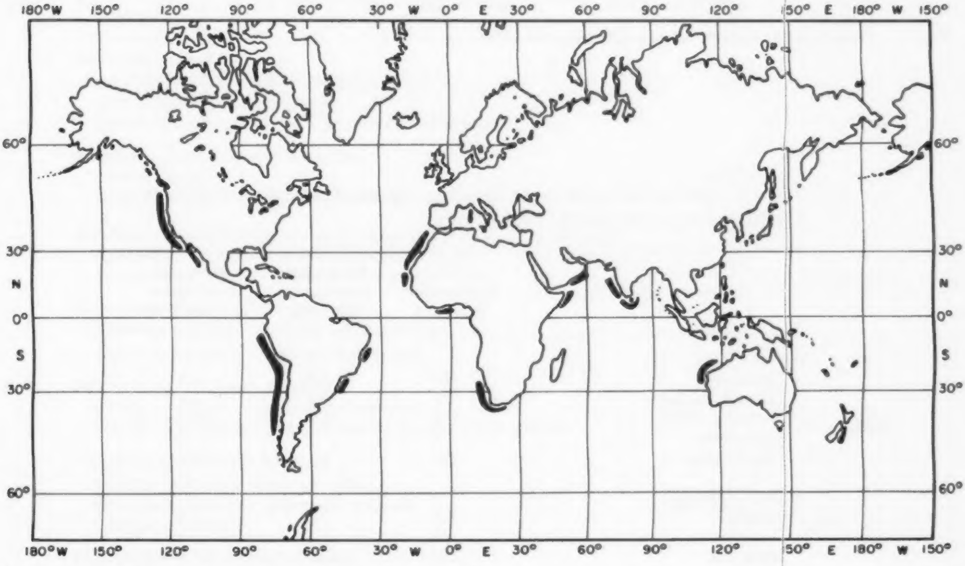

FIG. 2. Distribution of phosphatic deposits (Tooms 1967).

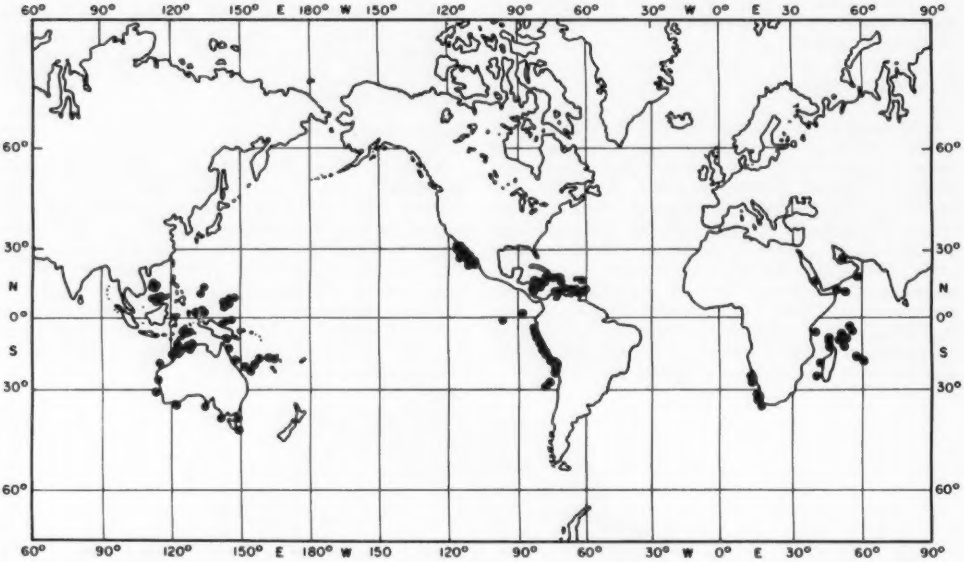

FIG. 3. Distribution of guano islands (Hutchinson 1950).

TABLE 2. Production in the major upwelling regions of the oceans in millions of metric tons per year (After Cushing 1969).

Area of upwelling	Primary production (carbon)	Secondary production (carbon)	Tertiary production (wet weight)
Pacific Ocean			
California	30	4.0	6.3
Costa Rica dome	15	2.3	3.5
Peru and Chile	155	15.8	28.0
Marquesas	?	?	?
New Guinea	40	1.2	4.7
Atlantic Ocean			
Canary	13	2.2	3.4
Guinea	?	1.4	2.9
Benguela	278	10.4	34.1
Indian Ocean			
Somalia–Southwest Arabia	50	3.1	7.4
Madagascar wedge	10	?	1.6
Orissa	10	1.3	1.9
Indo–Australian Archipelago	145	?	25.7

TABLE 3. Major stocks of herrings and sprats, with recent annual catches.

Species	Location	Wt
Atlantic herring (*Clupea harengus*)	North Atlantic Ocean	4,120,000 tons
Pacific herring (*Clupea pallasii*)	North Pacific Ocean	53,000 tons
Falkland herring (*Clupea fuegensis*)	Waters adjacent to southernmost South America	Not yet exploited commercially
Sprat (*Clupea sprattus*)	Northeastern Atlantic Ocean	200,000 tons

TABLE 4. Major stocks of temperate and subtropical clupeoid species.

	Catch in thousands of tons	
Area Species	Landed in 1970	Possible increase
East coast of USA		
Atlantic menhaden (*Brevoortia tyrannus*) Gulf menhaden (*B. patronus*)	600	
North Atlantic anchovy (*Engraulis encrasicholus*)		600
Southeast coast of South America		
Sardinella aurita	80–90	100
Argentine anchovy (*Engraulis anchoita*)		750
Southeast coast of Australia and adjacent waters of New Zealand		
Australian pilchard (*Sardinops neopilchardus*)	60	
Australian anchovy (*Engraulis australis*)		Unknown
Taiwanese–Korean–Japanese waters		
Japanese pilchard (*Sardinops melanosticta*)	10–20	
Japanese anchovy (*Engraulis japonicus*)	400	
Pacific coast of North America		
California pilchard (*Sardinops caerulea*)	20	
Northern anchovy (*Engraulis mordax*) and 3 other species		2000
Pacific coast of South America		
Chilean pilchard (*Sardinops sagax*)	70	
Peruvian anchoveta (*Engraulis ringens*)	8000–9000	
Clupea bentincki	80	Unknown
Eastern side of the Atlantic Ocean		
Sardine or European pilchard (*Sardina pilchardus*)	500	300
North Atlantic anchovy (*Engraulis encrasicholus*)		700
South African round and flat sardinellas (*Sardinella* spp.)		700
South African pilchard (*Sardinops ocellata*)	800	500
Cape anchovy (*Engraulis capensis*)	400	250
Round herring (*Etrumeus* sp.)		300

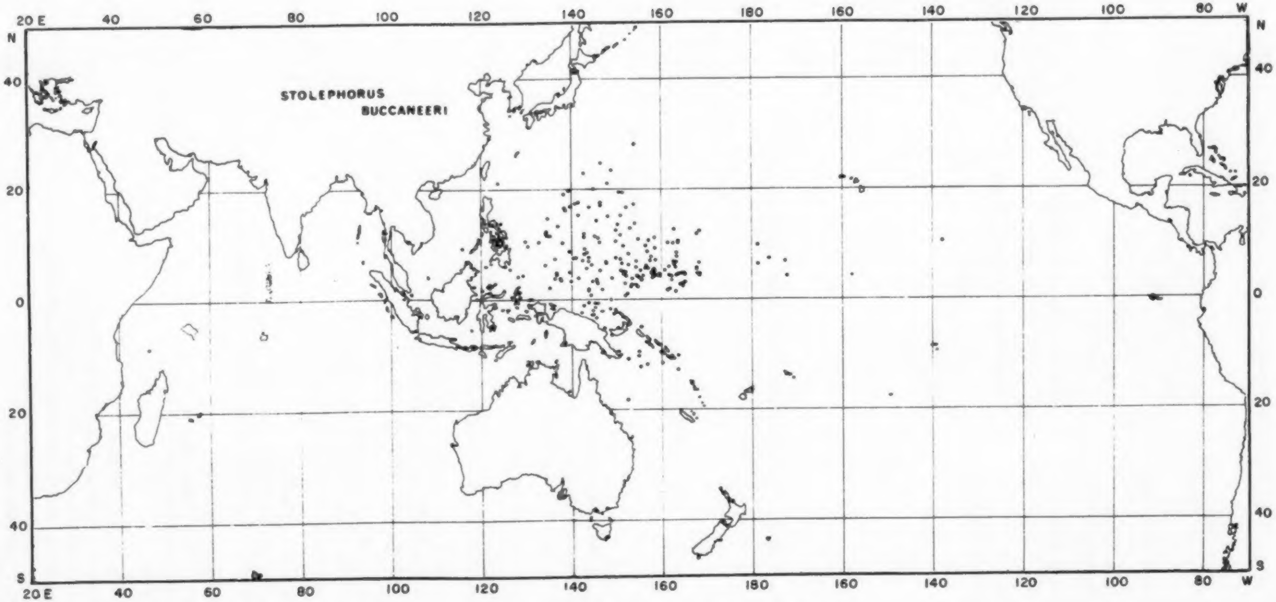
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FIG. 4. Larval distribution of *Stolephorus buccaneeri* in the Indo-Pacific Ocean (Ueyanagi et al. 1969).

TABLE 5. Major stocks of tropical clupeoid species.

Area Species	Catch in thousands of tons Landed in 1970	 Possible increase
Atlantic Ocean		
Gulf of Guinea		
Round and flat sardinellas (*Sardinella* spp.)		100
Anchovies		100
Tropical western Atlantic		
Venezuela sardine (*Sardinella anchovia*)	50	1500–2000
Anchovy (*Cetengraulis edentulus*)		
Thread herring (*Opisthonema oglinum*)		
Gulf menhaden (*Brevoortia patronum*)	750	
Eastern tropical Pacific Ocean		
Gulf of Panama		
Anchovy (*Cetengraulis mysticetus*)		100–500
Thread herring (*Opisthonema libertate*)		100–150
Other parts of the tropical coast		
Clupeoid fishes combined		500–1000
Indo-Australian Archipelago		
Sardinella albella	40	
S. fimbriata		
S. sirm		
Anchovies	20	
Western tropical Pacific Ocean		
Dussumieridae[a]		
Clupeidae[b]		
Engraulidae[c]		
Indian Ocean		
Oil sardine (*Sardinella longiceps*)	230	
Other *Sardinella* species	160	
Various species of anchovies	35	

[a] *Spratelloides delicatulus*, *S. japonicus*, and *Dussumieria hasselti*.

[b] *Amblygaster clupeioides*, *A. sirm*, *Sardinella jussier*, *S. melanura*, *Herengula ovalis*, and *Pollona ditchela*.

[c] *Stolephorus devisi*, *S. indicus*, *S. buccaneri*, and *Thrissina baelama*.

On the basis of recent catches and the estimates of the possible future catches given in Tables 3, 4, and 5, the potentials for these species are as follows:

Northern hemisphere — Atlantic anchovies on the east coast of USA, 600,000 tons; Atlantic anchovies in the northeastern Atlantic, 700,000 tons; Anchovies in the Californian upwelling area, 1,000,000–2,000,000 tons.

Southern hemisphere — Falkland herring off southern South America, 1,000,000 tons; Argentine anchovies, 750,000 tons; Australian pilchards and anchovies, 100,000 tons; Cape anchovies off South Africa, 1,250,000 tons; Round and flat *Sardinella* off southwestern Africa, 700,000 tons; Round herring off South Africa, 300,000 tons.

Tropical regions — Anchovies in the Gulf of Mexico and Caribbean, 1,500,000–2,000,000 tons; *Sardinella* and anchovies in the Gulf of Guinea, 200,000 tons; Anchovies and thread herrings off the Pacific coast of Central America, 700,000–1,650,000 tons; Oil sardines in the Arabian Sea: the potential catch may not be large; Various anchovies, thread herrings, and other clupeoids in the Indo-Australian Archipelago: reliable information is not available, but the potential catch appears to be very large.

HORSEMACKERELS AND SCADS

The various species of horsemackerels (*Trachurus*) are found beyond 40°N in the Pacific and 50°N in the Atlantic Ocean; scads (*Decapterus*) occur in warmer waters. These fishes occupy a higher level in the food chain than clupeoids but a lower one than mackerels. They live on small fishes and zooplankton but feed more on plankton than the mackerels, hence hook-and-line fishing is not as effective. Their fishing grounds are usually close to continental coasts or islands and the catch often fluctuates significantly. Productive areas are similar to those for clupeoids. The most intensive fishing is in Japanese waters, the Japanese catch of *Trachurus japonicus* being 250,000 tons a year. Other landings include: 10,000 tons in the Peru–Chile area (Chilean horsemackerel, *T. murphyi*); 200,000 tons in the European area (Atlantic horsemackerel); 200,000 tons along the South African coast (maasbanker, *T.t. capensis*).

The total world catch of scads is about 400,000 tons a year, the major part coming from the Indo-Australian Archipelago. There are still wide areas without a significant fishery, totalling perhaps twice the area covered by present commercial fisheries. Even in the exploited areas, except for the Japanese catch, the scad landings have been smaller than those of mackerels, perhaps because of smaller demand.

Possible increase in the catch of this group is as follows:

Tropical waters — West coast of central Africa: horsemackerel and mackerel, 100,000–500,000 tons; Indo-Australian Archipelago and Arabian Sea: scads and horsemackerel, more than 500,000 tons.

Northern hemisphere — California coast: Pacific jack mackerel (*Trachurus symmetricus*), 300,000–800,000 tons.

Southern hemisphere — Australian waters: horsemackerel standing crop, 50,000 tons; Chilean waters: Chilean horsemackerel and mackerel, 100,000 tons; South African waters: maasbanker, 600,000 tons.

MACKERELS

Mackerels occur in the temperate and tropical waters of both hemispheres. These fish are more coastal in character than tunas but more oceanic than scads and horsemackerels. Major commercial fisheries have developed in the northern hemisphere. Table 6 lists the major species and their occurrence throughout the world, and the catch and fishing methods used. The Japanese, spotted, North Atlantic and Pacific mackerels have been exploited on a commercial basis, while recently a fishery for Indian mackerel has developed in the Gulf of Thailand.

Mackerels are second-stage carnivores, ranking above sardines and horsemackerels but below tunas in the food chain. They consume small fishes and zooplankton, so their major grounds are similar to those of sardines and anchovies.

The following increases in catch are possible:

Spotted mackerel — 200,000–400,000 tons
Pacific mackerel — 40,000 tons
Mackerel (and horsemackerel) off west central Africa — 100,000–400,000 tons
Indian mackerel — 500,000 tons

The Indian mackerel is a typical tropical species. Its present catch is 60,000–100,000 tons from the Gulf of Thailand, and the fish is also caught along the coast of the Indian Ocean, probably about 30,000 tons a year. No significant catch has been recorded from other parts of its range. The present catch of 90,000–130,000 tons from

TABLE 6. Major stocks of mackerels.

Species	Area of occurrence	Fishing gear
Japanese mackerel (*Scomber japonicus*)	Waters adjacent to Japan	Purse seine and hook-and-line
Spotted mackerel (*S. tapeinocephalus*)	Waters adjacent to Japan	Purse seine and hook-and-line
Mackerel (*S. scombrus*)	Both coasts of the North Atlantic	Purse seine
La Plata mackerel (*S. japonicus marplatensis*)	SE coast of South America	
Chub mackerel (*S. japonicus diego*)	Pacific coast of North America	Purse seine
Bullseye mackerel (*S. grex*)	E coast of America	
African mackerel (*S. colias*)	NW to SW coasts of Africa	
Peruvian mackerel (*S. peruanus*)	NW coast of South America	
Australian mackerel (*S. australis*)	E coast of Australia and waters adjacent to New Zealand	
Indian mackerel (*Rastrelliger kanagurta* and *R. neglectus*)	Indo–Australian Archipelago tropical coast of the Indian Ocean	Purse seine and trawl

a limited area suggests the possibility of an increased catch from such regions as the Arabian Sea, the inland sea areas of the Indo-Australian Archipelago, and the waters of New Guinea areas where upwelling takes place. As this adds up to a vast area outside the established fisheries, the present catch may perhaps be increased many times. A tentative estimate is about 500,000 tons per year.

Oceanic Pelagic Fishes

Fishes of the oceanic pelagic group occur in the surface layer; they are important natural foods for large carnivorous fishes.

FLYINGFISHES (OXYPORHAMPHIDAE AND EXOCOETIDAE)

The flyingfishes comprise about 60 species (Parin 1967) of tropical and subtropical regions (Fig. 5). Some species are found in neritic waters, others only in the offshore area, while some occur in both. Distribution of larvae of *Exocoetus volitans*, one of the tropical species, is illustrated in Fig. 6. Parin (1967) has demonstrated that the distribution of flyingfish is correlated with water temperature.

Fish of this group rarely exceed 50 cm in length. The lengths of *Cypselurus opisthopterus* and *C. heterus döderleini* caught commercially in the Japan Sea range from 20 to 30 cm (Okachi 1958). Okachi and Parin both suggest that these fish grow quickly and mature by the end of their first year. They feed on planktonic crustaceans, molluscs and other plankton animals, sometimes also on young fishes.

Flyingfishes are exploited on a small scale in tropical and subtropical regions, including Polynesia, the Philippines, India, and Vietnam. Gears used are hook-and-line, trapnets, gillnets, and purse seines. The fishery is more mechanized in Japan where the principal gear is the gillnet. Annual catches for 1965 to 1969 were:

	Japanese catch	World catch
1965	12,000 tons	22,000 tons
1966	10,000 tons	23,000 tons
1967	10,000 tons	25,000 tons
1968	12,000 tons	25,000 tons
1969	14,000 tons	27,000 tons

On the basis of comparisons between the Japanese fishing regions and the total of tropical coastal regions it may not be unrealistic to expect an eventual world catch of 100,000 tons from coastal areas. Adding the catch from offshore areas, the overall potential may be much larger. However, this group includes a great many species with different distributions and behavior, and much more information is needed before full exploitation can be undertaken. The widely scattered nature of the species will make efficient exploitation difficult.

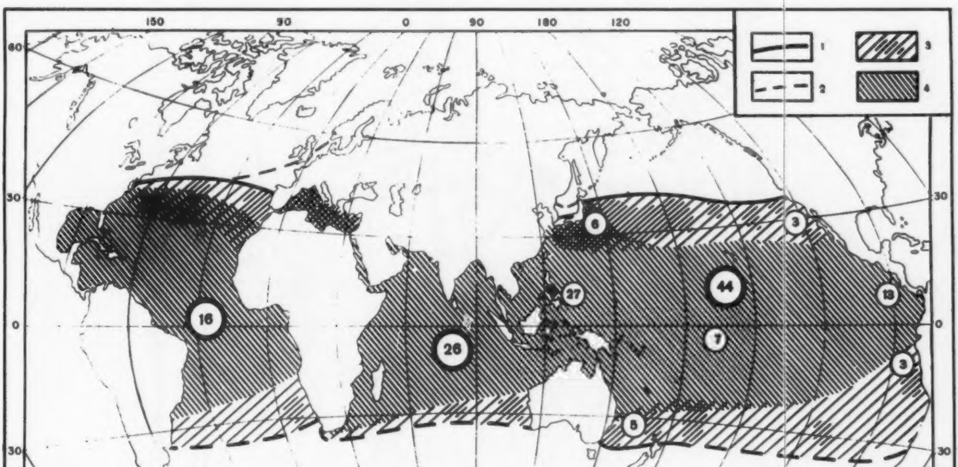


FIG. 5. Distribution of flying fishes in the world ocean (Parin 1967). 1, Northern and southern limits of occurrence of *Exocoetidae*; 3, Range of distribution of *Hirundichthys rondeletii*; 4, Range of distribution of tropical species of flying fish.

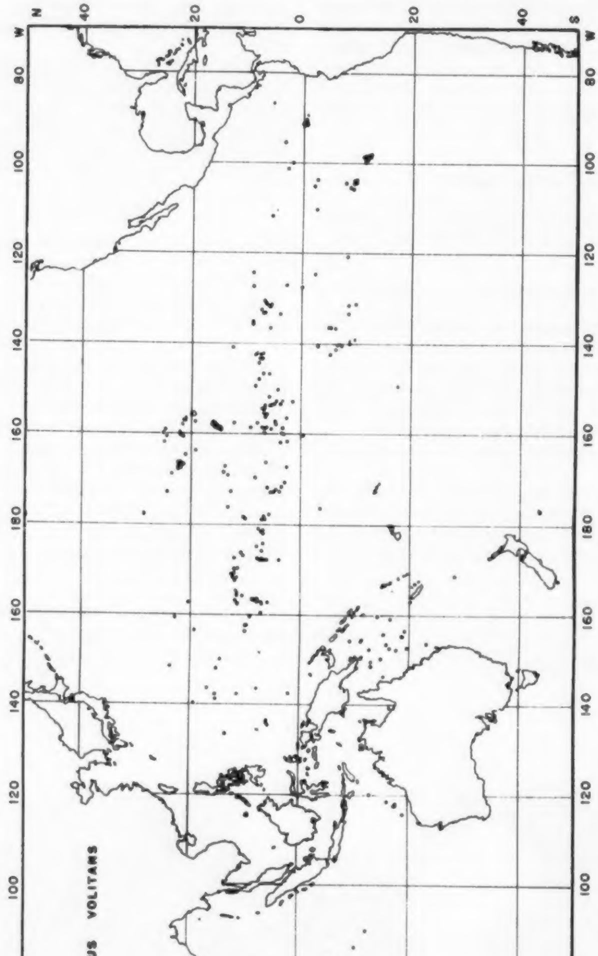

EXOCOETUS VOLITANS
20 E
40
60
80
100
120
140
160
180
160
140
120
100
80
W
N
40
20
0
20
40
S

FIG. 6. Occurrence of *Exocoetus volitans* in larval net samples from the Indo-Pacific Ocean (Ueyanagi et al. 1966).

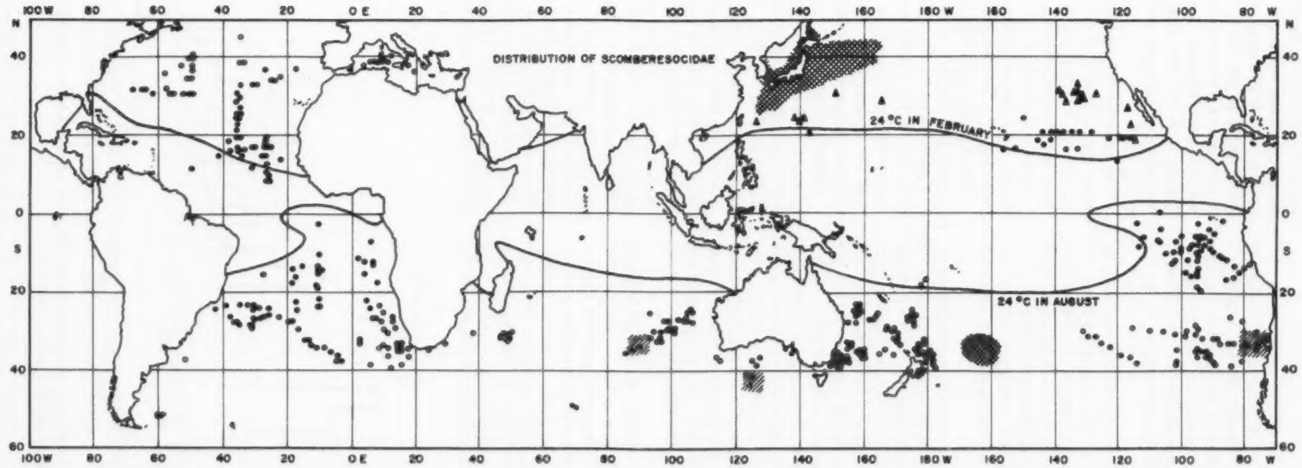

DISTRIBUTION OF SCOMBERESOCIDAE
24°C IN FEBRUARY
24°C IN AUGUST
100W 80 60 40 20 0E 20 40 60 80 100 120 140 160 180W 160 140 120 100 80 W
N 40 20 0 5 20 40 60

FIG. 7. Distribution of larvae and pre-adults of four species of saury (Ueyanagi et al. 1969; Ueyanagi and Doi 1971; Ueyanagi et al. 1972). (Open circles, *Scomberesox saurus* (larvae); Closed circles, Pacific: *Cololabis adocetus* (larvae); Closed circles, Atlantic: *Scomberesox* sp.; Triangles: *Cololabis saira* (larvae); Shaded areas: Juveniles and adults.)

Sauries (Scomberesocidae)

Sauries comprise four species: Pacific saury (*Cololabis saira*) in the North Pacific, Pacific dwarf saury (*C. adocetus*) in the subtropical area of the eastern Pacific, Atlantic saury (*Scomberesox saurus*) in the temperate zones of the southern hemisphere and the North Atlantic, and the Atlantic dwarf saury (*Scomberesox sp.*) in the subtropical Atlantic.

The Pacific saury has been substantially exploited by Japan and USSR but some stocks are thought to be underexploited in the central and eastern Pacific. Much biological information for this species is available, particularly concerning stocks of the northwestern Pacific.

The occurrences of larval and subadult sauries are summarized in Fig. 7. The four species occur in separate areas that scarcely overlap.

The distribution of Atlantic sauries (also called skippers or saury pike) coincides with the West Wind Drift. As a result, it occurs widely in the temperate portion of the southern hemisphere zone and in the North Atlantic. The northern group is separated from the southern one by the equatorial area. It should be noted that larvae of the skipper are centered in the lower latitudes of its range, where the temperature range is from 14 to 23 C (Ueyanagi et al. 1972). The temperature range where skippers are caught by lift nets is from 10 to 23 C (Parin 1968).

Cololabis adocetus is restricted to the subtropical region of the Pacific Ocean east of 160°W. In the northern hemisphere it occurs between 15 and 25°N, and in the southern hemisphere from the Equator to 15°S. Its temperature range is 21–25 C.

A species of *Scomberesox* occurs in the subtropical area of the Atlantic Ocean, where it has a distribution pattern similar to that of *Cololabis adocetus* in the Pacific.

The various species of sauries school near the surface. Berman and Ruizenko (1968) observed a seasonal change in surface schooling of *Scomberesox saurus* in the South Pacific Ocean. In the area just north of the West Wind Drift schools of adult and immature fish are not very common in May, but their density increases in June. This suggests that there is a northern migration of saury in the southern winter, although some are to be seen in the area at all seasons. The lengths of skippers caught by lift nets using lights range from 15 to 40 cm (Fig. 8) perhaps because there are several age groups (Birman and Ruizenko 1968). Adult skippers are remarkably phototactic, and fishing with lift nets and lights is effective. The length frequency of samples collected by larval nets is shown in Fig. 9.

The growth rate of the species is similar to or a little more rapid than that of the North Pacific saury, which matures at 3 or 4 years of age and does not attain maximum length until it is about 5 or 6 years old.

Cololabis adocetus is a dwarf species of up to 6 cm in length. The fish are plankton grazers and they are easily collected by a larval net at the surface.

The Atlantic dwarf saury (*Scomberesox* sp.) is another pygmy. The life history of this species is similar to that of *Cololabis adocetus*. The larvae range from 5 to 10 mm (Fig. 9). Parin (1968) estimates the minimum size of mature fish at about 9 cm. Ueyanagi et al. (1972) suggest that the skipper may leave the planktonic stage earlier than the Atlantic dwarf saury.

Prospects for greater utilization of sauries in future are good. *Cololabis saira* has long been utilized in the Northwest Pacific, with an annual catch fluctuating from 60,000 to 500,000 tons. The average for 1960–69 was 274,000 tons. Based on the frequency of larval occurrences in plankton nets (Ahlstrom 1968), the potential catch in the California area is estimated at about 100,000 tons. Assessment of the potential in the middle North Pacific has not yet been attempted. The biomass of *Scomberesox saurus* seems to be much larger than that of any of the other three species and the average size of the fish is large enough for commercial utilization. The dwarf species, however, are too small. Because of their remarkable phototaxis, skippers could probably be best exploited by lift nets and lights. From its incidental catches in coastal areas and from the occurrence of its larvae, it appears that there are large resources of skippers in various parts of the world. Tentative estimates of the possible catch

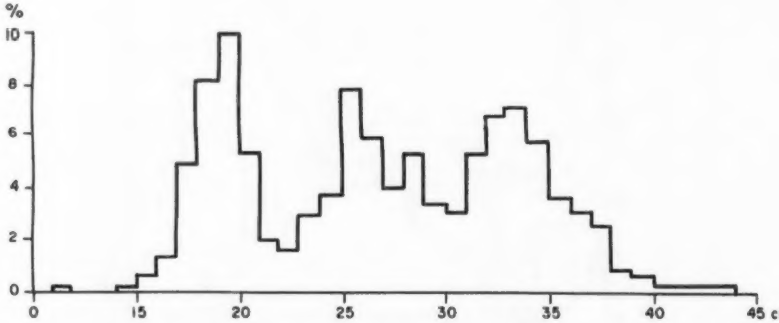


FIG. 8. Length frequency distribution of skipper (*Scomberesox saurus*) caught by liftnets using lights (Birman and Ruizenko 1968).

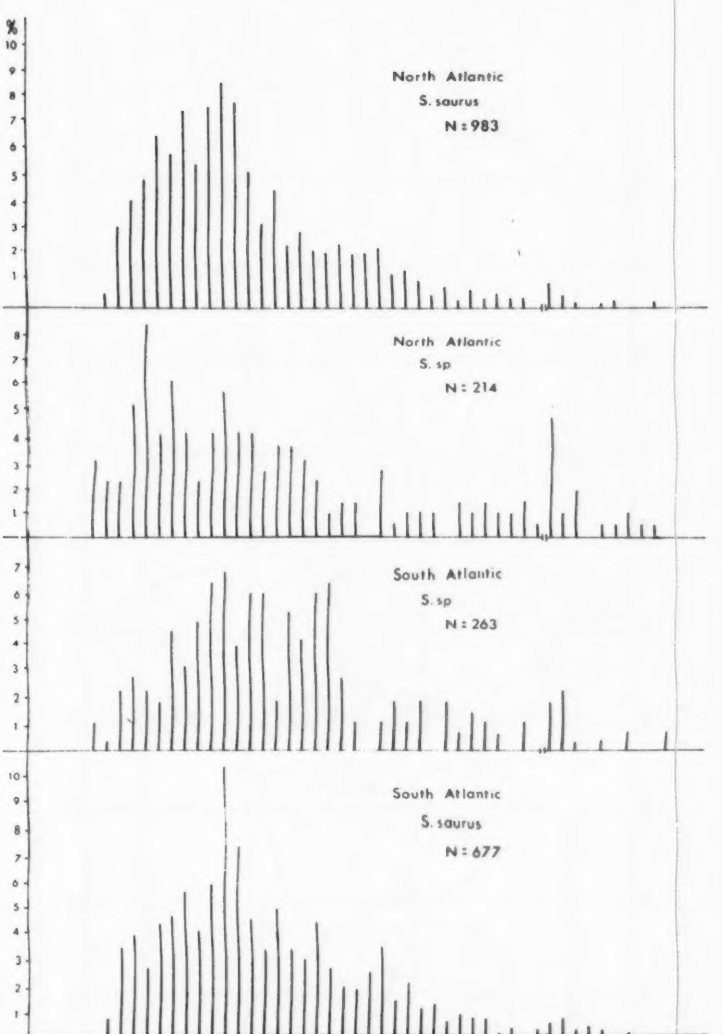


FIG. 9. Length-frequency distribution of skippers (*Scomberesox saurus*) and Atlantic pigmy sauries (*S.* sp.) sampled by larval nets (Ueyanagi et al. 1972).

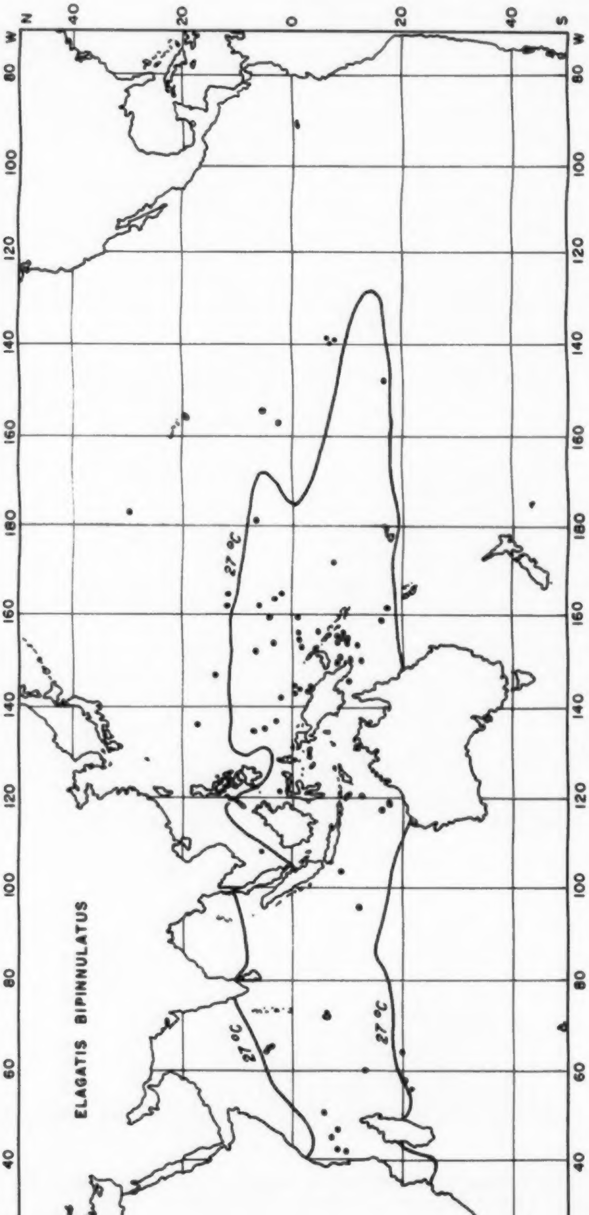

ELAGATIS BIPINNULATUS
27 °C
27 °C
27 °C
20 E
40
60
80
100
120
140
160
180
160
140
120
100
80 W
N
40
20
0
20
40
S

FIG. 10. Occurrence of larval and juvenile rainbow runners (*Elagatis bipinnulatus*) in the Indo-Pacific area (Okiyama 1970).

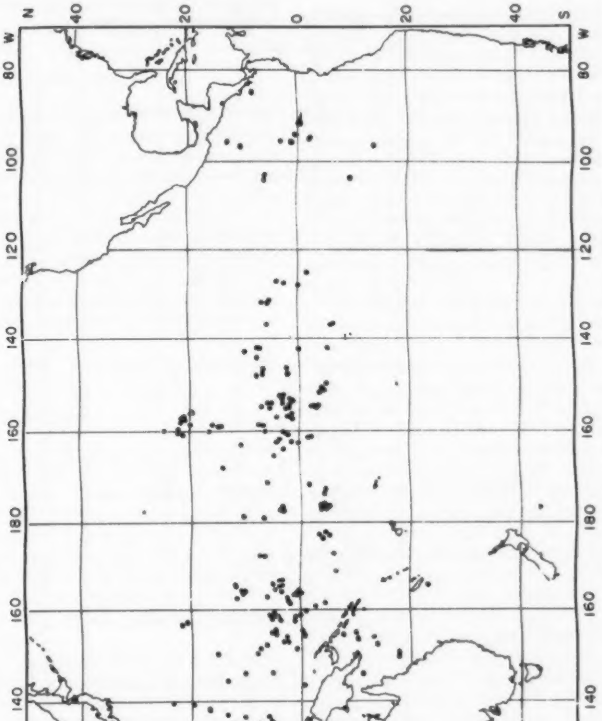

CORYPHAENA EQUISELIS
20 E
40
60
80
100
120
140
160
180
160
140
120
100
80 W
N
40
20
0
20
40
S

FIG. 11. Distribution of *Coryphaena equisetis* larvae in the Indo-Pacific area (Ueyanagi et al. 1969).

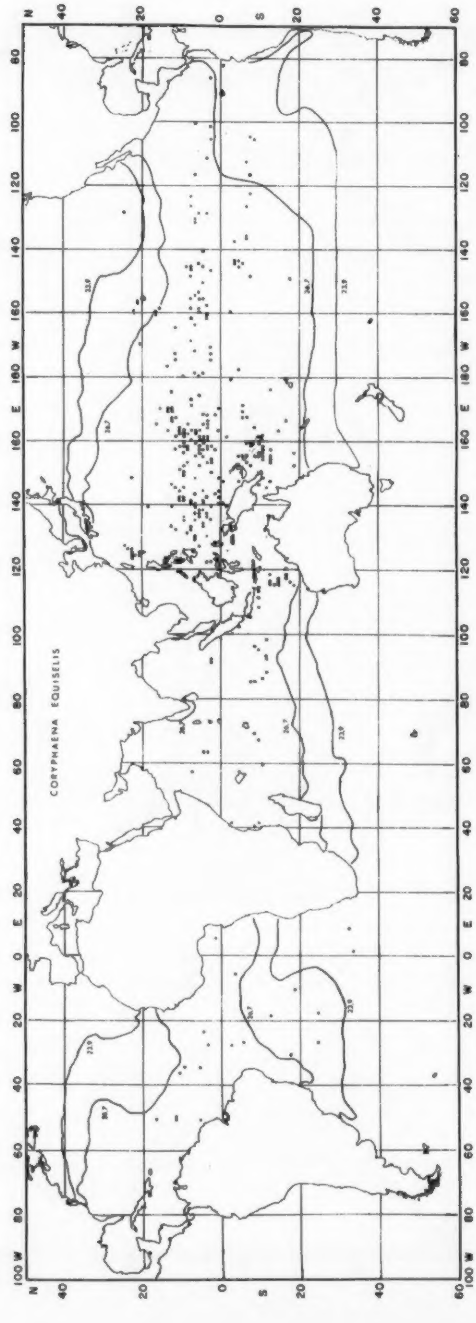

CORYPHAENA EQUISELIS
100 W
80
60
40
20
W 0 E
20
40
60
80
100
120
140
160
E 180 W
160
140
120
100
80
N 40
20
0
S
20
40
60
26.7
22.9

FIG. 12. Occurrence of juvenile and adult *Coryphaena equisetis* in the stomach contents of tunas and marlins (K. Mori et al. unpublished data).

in the southeastern Atlantic Ocean are several hundred thousand tons, and it is likely that several times this amount could be caught if the entire stock of this species were effectively exploited.

RAINBOW RUNNERS (*Elagatis bipinnulatus*)

This fish occupies a higher trophic level than flyingfishes and sauries but is lower than tunas and marlins. There are no substantial fisheries for this species, and little information on its life history in the offshore area. Most of the information is based on the stomach contents of large carnivorous fishes and larval net samples.

The occurrence of larval and juvenile rainbow runners is illustrated in Fig. 10. This indicates that most spawning is in the coastal waters of tropical regions. As they grow, the fish move offshore. Little is known about distribution and behavior at the adult stage, but on the evidence of the frequent occurrence of adult fish in offshore areas and the abundance of this species in larval nets, its biomass seems to be large (Okiyama 1970).

DOLPHINFISHES (CORYPHAENIDAE)

Dolphinfishes occupy an ecological niche similar to the rainbow runner, as described above. Two species are found in the Pacific Ocean — the common dolphin (*Coryphaena hippurus*) of the coastal region and *Coryphaena equisetis* of the offshore area. Larvae of the latter occur over wide oceanic areas (Fig. 11). It is not unusual to find young (length 10 to 20 cm) of these species in the stomach contents of tunas and marlins (Fig. 12). This suggests an important role for the species in the food chain in the offshore area.

Coryphaena equisetis is caught incidentally in the commercial fishery for *C. hippurus* in the southwestern Japan Sea. It measures about 60 cm and is 0.8 to 1.0 kg in weight on the average; a probable maximum size is less than 100 cm (Uchida 1935). The minimum length of mature females is 20–25 cm (Mori 1973). Presumably this pecies does not grow as large as *C. hippurus*.

SMALL TUNAS

While the stocks of large tunas are already fully utilized, an increased catch of small tunas is possible. The group includes about 10 species, as listed in Table 7.

The larval distribution of small tunas (with the exception of skipjack and slender tuna) is substantially different from that of the large species. Larval black skipjack occur close to land (Fig. 13). There are three known major centers of larval occurrence: southeast Asia, the tropical eastern Pacific, and the Caribbean Sea. The larvae of frigate mackerels also occur in coastal waters (Fig. 14). No information on the larval distribution of longtail tuna is available. Larvae of slender tuna occur over a wide subtropical offshore area mostly in the southern hemisphere (Fig. 15).

The skipjack catch by the live bait fishery in waters adjacent to Japan is shown in Fig. 16. A large catch occurs in areas of interface between currents and around islands. The fish are of medium size (40–60 cm). Skipjacks more than 55 cm long are distributed widely and evenly in tropical waters (Fig. 17). The occurrence of larvae is shown in Fig. 18. Skipjacks of medium size are more widespread. Thus, it is deduced that skipjacks are hatched in tropical waters and expand southward and northward as they grow. On reaching 55 cm they mature and become concentrated again in the spawning areas at low latitudes.

The distributions of other small tunas at the adult stage are not well known because of the absence of commercial fisheries. But the distribution of larvae and incidental catches of adult fish suggest that black skipjack and frigate mackerels occur frequently in inshore waters at low latitudes. Incidental catches of adult longtail tuna by trolling and longlining suggest that this species occurs in coastal areas, especially over the wider continental shelves.

A small quantity of adult slender tuna is caught with southern bluefin tuna in the West Wind Drift. Slender tuna may be distributed in waters of the West Wind Drift at the adult stage (Fig. 15; see also Warashina and Hisada 1972).

TABLE 7. Small tunas and bonitos of the Atlantic (A), Pacific (P), and Indian (I) oceans.

English name	Scientific name	Maximum size (*kg*)	Utilization	Region	Oceans	Present catch (*tons*)
Blackfin tuna	*Thunnus atlanticus*	20	canned	Tropical	A	
Longtail tuna	*Thunnus tongol*	30	canned	Tropical	P, I	
Skipjack tuna	*Euthynnus pelamis*	20	canned, fresh and dried	Tropical	P, I, A	303,000
Little tunas	*Euthynnus affinis,* *E. lineatus,* *E. alletteratus*	20	fresh, dried	Tropical	P, I, A	30,000
Frigate and bullet mackerel	*Auxis thazard,* *A. rochei*	10	dried	Subtropical to tropical	P, I, A	36,000
Slender tuna	*Allothunnus fallai*	30	?	Temperate	P, I, A	
Bonitos	*Sarda* spp.	15	canned, fresh	Tropical to subtropical	P, I, A	118,000

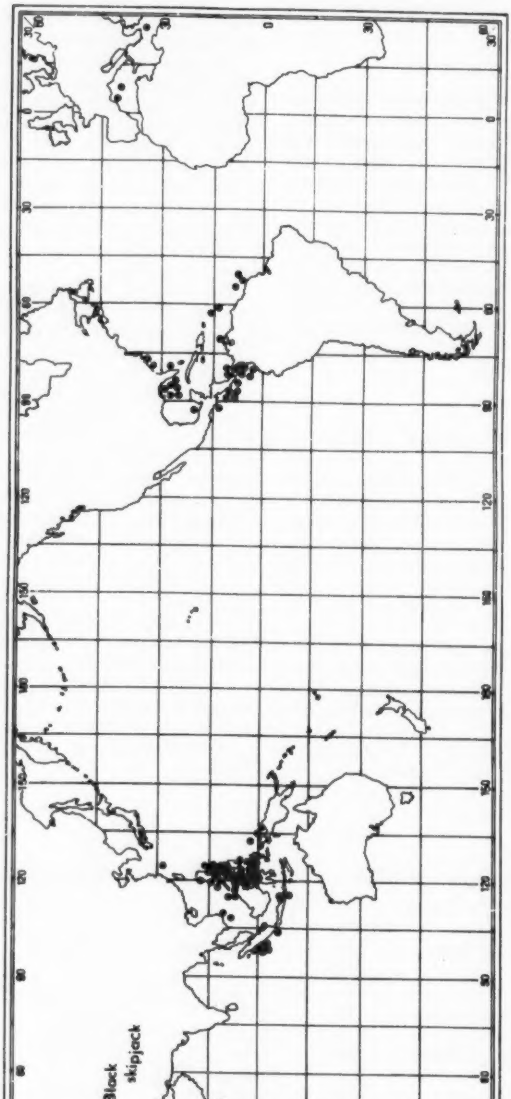

Black
skipjack

FIG. 13. Larval distribution of black skipjack (Yabe et al. 1963).

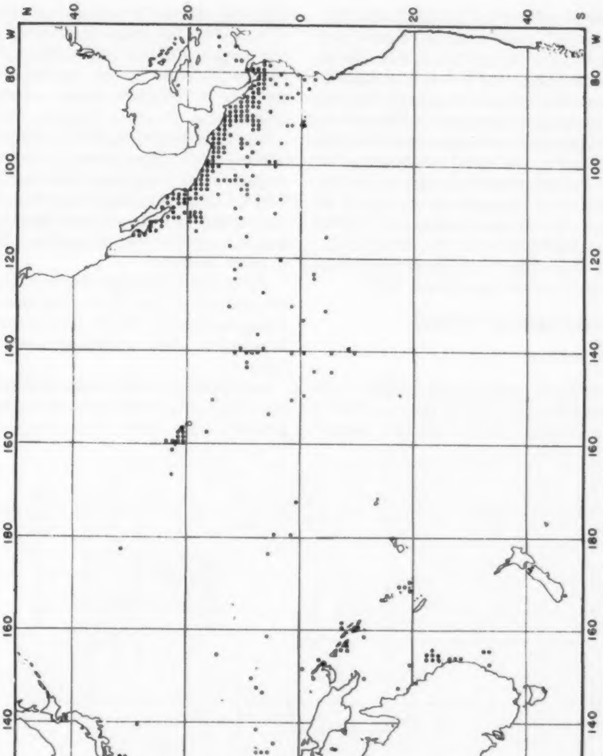

FRIGATE MACKEREL
20 E
40
60
80
100
120
140
160
180
160
140
120
100
80
W
N
40
20
0
20
40
S

FIG. 14. Distribution of larval frigate mackerels (S. Ueyanagi unpublished data).

Skipjack tuna and bonitos in the Pacific Ocean have been substantially exploited commercially. Recently a skipjack fishery in the eastern part of the Indian Ocean has been developing quickly and its catch is now 30,000–40,000 tons. The catch of skipjack in the eastern Atlantic Ocean is also increasing, and amounted to 20,000 tons in 1971. Other stocks hold possibilities for increases in catch but their extent is not known. Increased catches of skipjacks in the Pacific and Indian oceans are expected. In the Pacific the possible catch of skipjacks is estimated at 500,000–600,000 tons; in the Indian Ocean it is 160,000 tons and in the Atlantic 250,000 tons (Gulland 1972). The world potential is set at 1.2–1.5 million tons on the basis of frequency of larval occurrence (Suda 1969).

Oceanic Mesopelagic Fishes

LANTERNFISHES (MYCTOPHIDAE)

Lanternfishes include many genera and perhaps 200 species of mesopelagic forms occurring at depths of 200–1000 m. They are distributed widely, but the species composition varies with the water mass. Occurrence of some species has been reported from the Bering Sea and Spitsbergen and from the shelf of the antarctic continent. Except for some neritic species, these fish are deep-sea dwellers in offshore areas, which makes their study difficult.

Myctophids are small fishes from 2.5 to 25 cm in length (Parin 1968), with numerous "eye-spots" or luminescent organs. Their life span is about 4–5 years or less (Parin 1968). During daytime, these fish stay at depths down to more than 500 m, at night they come up to shallower layers, sometimes to the surface. Phototaxis is observed in some species.

Parin (1968) arranges the distribution of myctophids in 10 groups; that of *Centrobranchus* is shown in Fig. 19. Kawaguchi et al. (1972) have plotted the distribution of *Myctophum* from collections made in larval nets (Fig. 20, a–e).

Parin (1968) summarizes available information on exploitation. Myctophids are schooling species and are an essential component of the deep-scattering layer (DSL).

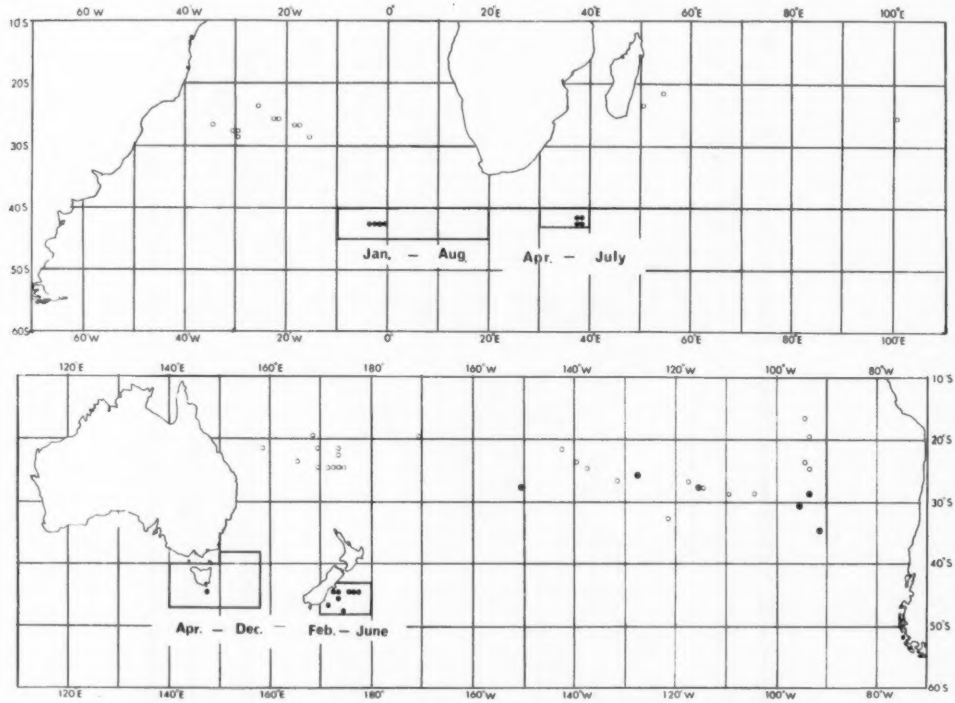


FIG. 15. Distribution of larval, young and grown slender tuna. (Open circles: Larvae reported by Watanabe et al. (1966) and Mori (1967–71); Circle within circles: Young reported by Mori (1967–72); Closed circles: Grown fish caught by Japanese longliners, 1968–71; Bold quadrangles: areas where the grown fish were taken.)

The density of *Stenobrachius nannochir* in the Okhotsk Sea is 3–5 per m^3. The group as a whole is an important natural food of cod, salmon, rockfishes, tunas, and fur seals,

Ueyanagi et al. (1969) reported that, of pelagic fish larvae collected by net from offshore areas in the Pacific and Indian oceans, more than 60% were myctophids. Similar observations have been reported from various parts of the world, suggesting that the biomass of the group is enormous. But their deep swimming habits and their small size are discouraging factors for commercial utilization.

If harvesting were feasible, several hundred thousand tons of myctophids could probably be caught from each of the northwestern, southwestern, and southeastern parts of the North Atlantic Ocean, the northeastern, eastern central, and southeastern parts of the Pacific Ocean. For the Indian Ocean no quantitative assessment is available, but three quarters of pelagic eggs and larvae from the net samples here are of myctophids and gonostomatids. In the South African area, anchovy nets often catch myctophids (mainly *Lampanyctus hectoris*) at 30–260 m, sometimes with anchovies and sometimes alone. These fish weigh 0.8–3.1 g. Oil extraction efficiency is good, amounting to 110 liters/ton.

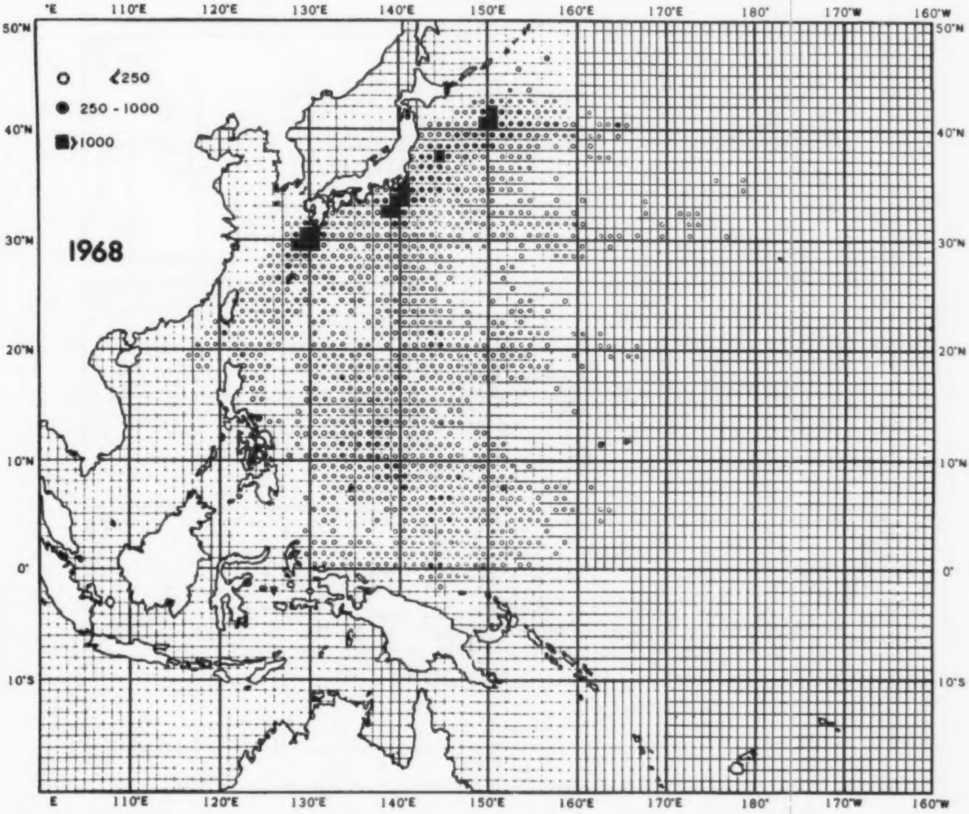


FIG. 16. Distribution of skipjack caught by the live-bait fishery in waters adjacent to Japan, 1968.

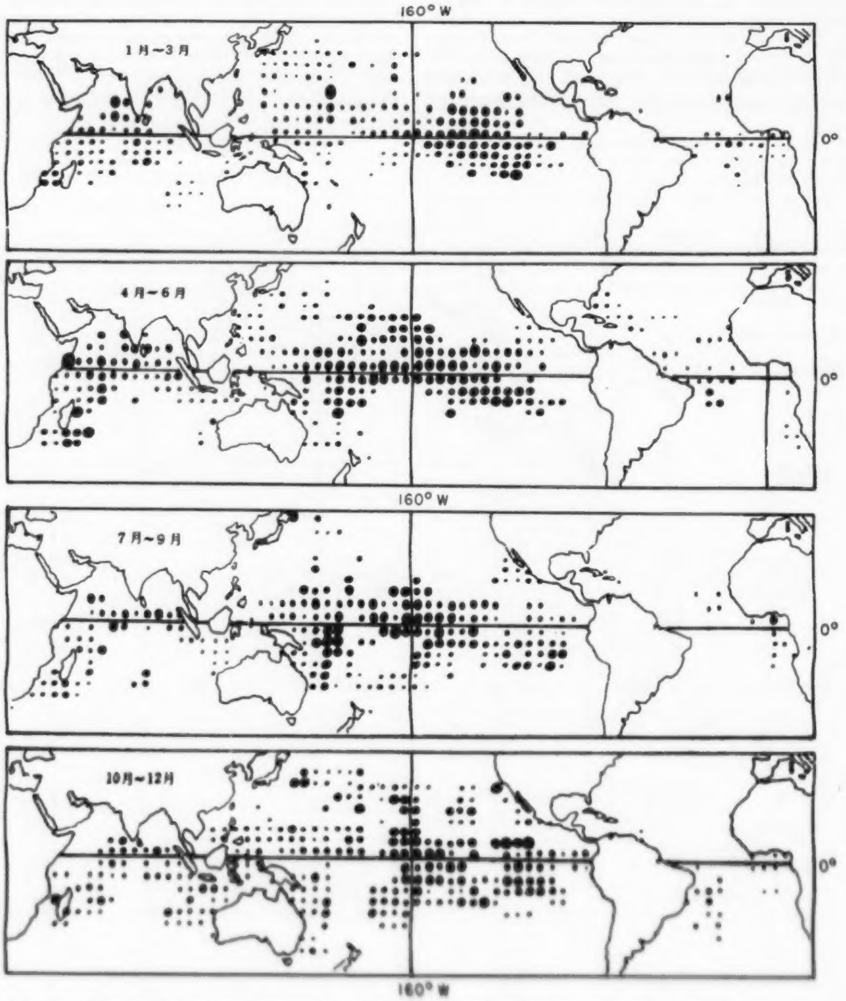

160° W
1月~3月
0°
4月~6月
0°
160° W
7月~9月
0°
10月~12月
0°
160° W

FIG. 17. Distribution of longline-caught skipjacks in the world Ocean (Kasahara 1968).

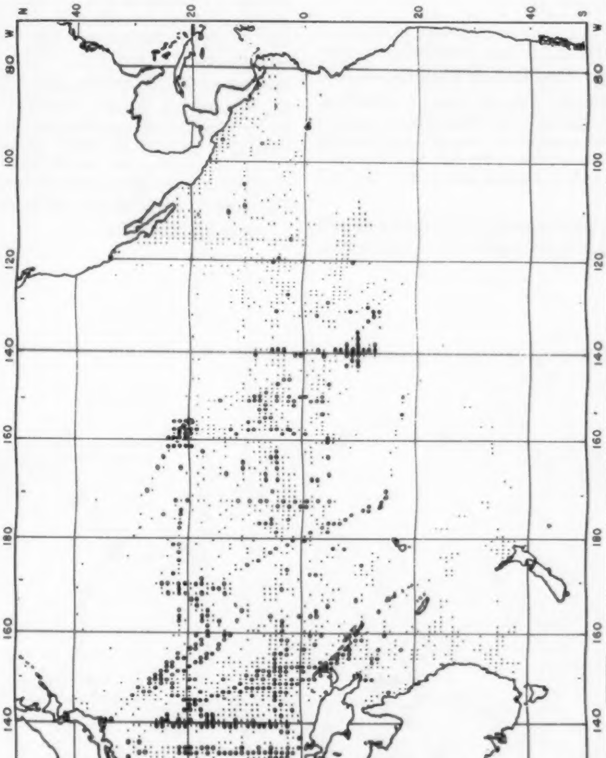

SKIPJACK
MAY ~ OCT.
20 E
40
60
80
100
120
140
160
180
160
140
120
100
80 W
N
40
20
0
20
40
S

Fig. 18. Distribution of larval skipjacks in the Indo-Pacific Ocean (Ueyanagi 1969).

LIGHTFISHES (GONOSTOMATIDAE)

The gonostomatids are small mesopelagic and bathypelagic fishes. Like myctophids they have rows of luminous spots on the body. They feed on plankton and are eaten by cod and rockfishes. They are also an important element of the deep-scattering layer. The group includes about 20 genera. Gonostomatids are found down to 2000 m, and their density and species composition vary significantly with depth. Little is known about their diurnal vertical migrations.

The distribution of certain species of *Cyclothone* in the Pacific Ocean has been summarized by Mukhacheva (1968). As shown in Fig. 21, the pattern of distribution differs between species. Ueyanagi et al. (1969) reported that species of *Vinciguerria* are more concentrated in the eastern Pacific Ocean (Fig. 22). However, available information is not sufficient to determine their areas and seasonal changes in density. *Vinciguerria lucetia* is one of the most abundant pelagic fishes in the eastern North Pacific (Ahlstrom and Counts 1958). Mukhacheva (1966) considered *Cyclothone* to be one of the most abundant fishes in the bathypelagic zone, and Ueyanagi et al. (1969) are of the same opinion because of its frequent occurrence as larvae in plankton nets.

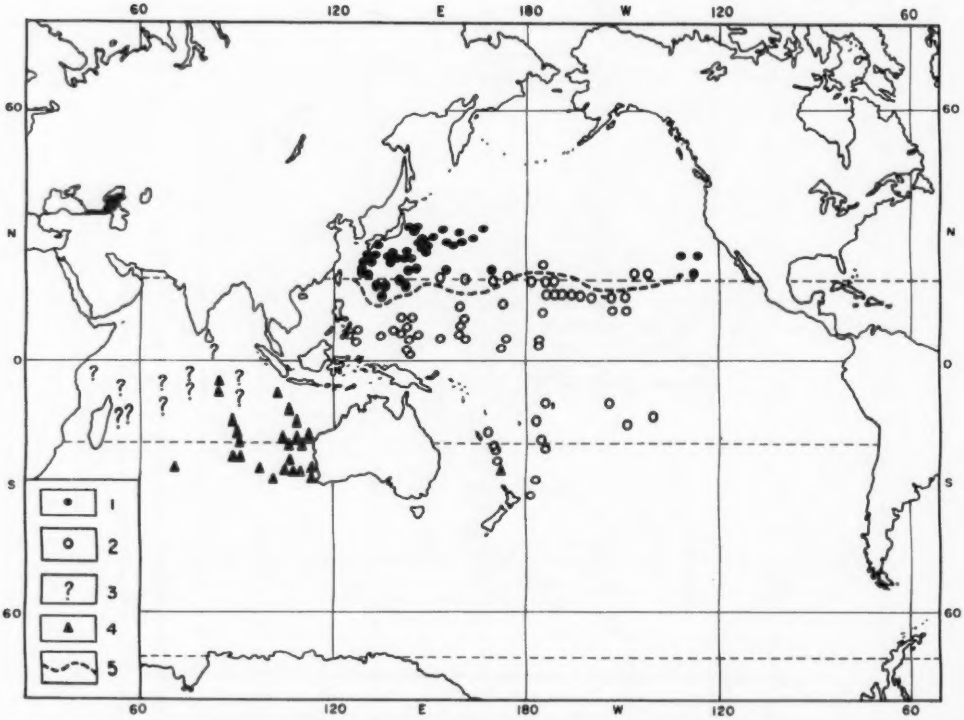
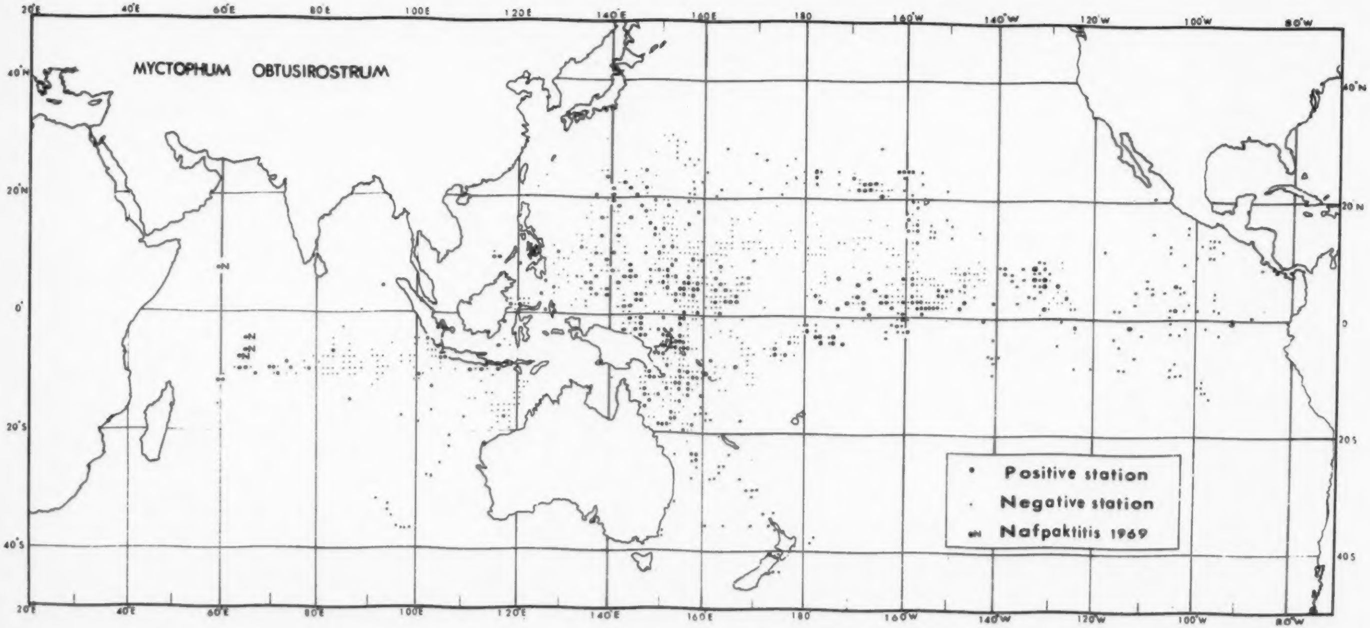
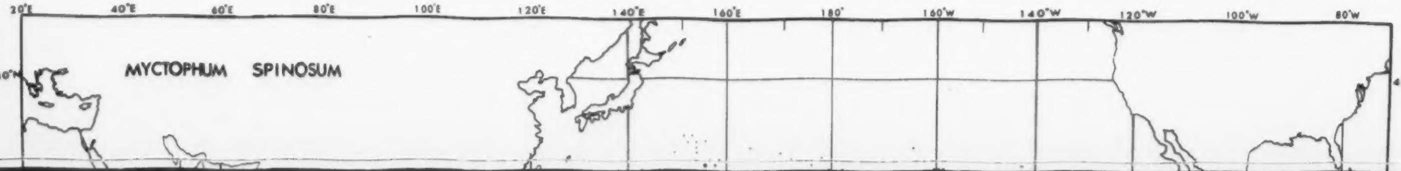
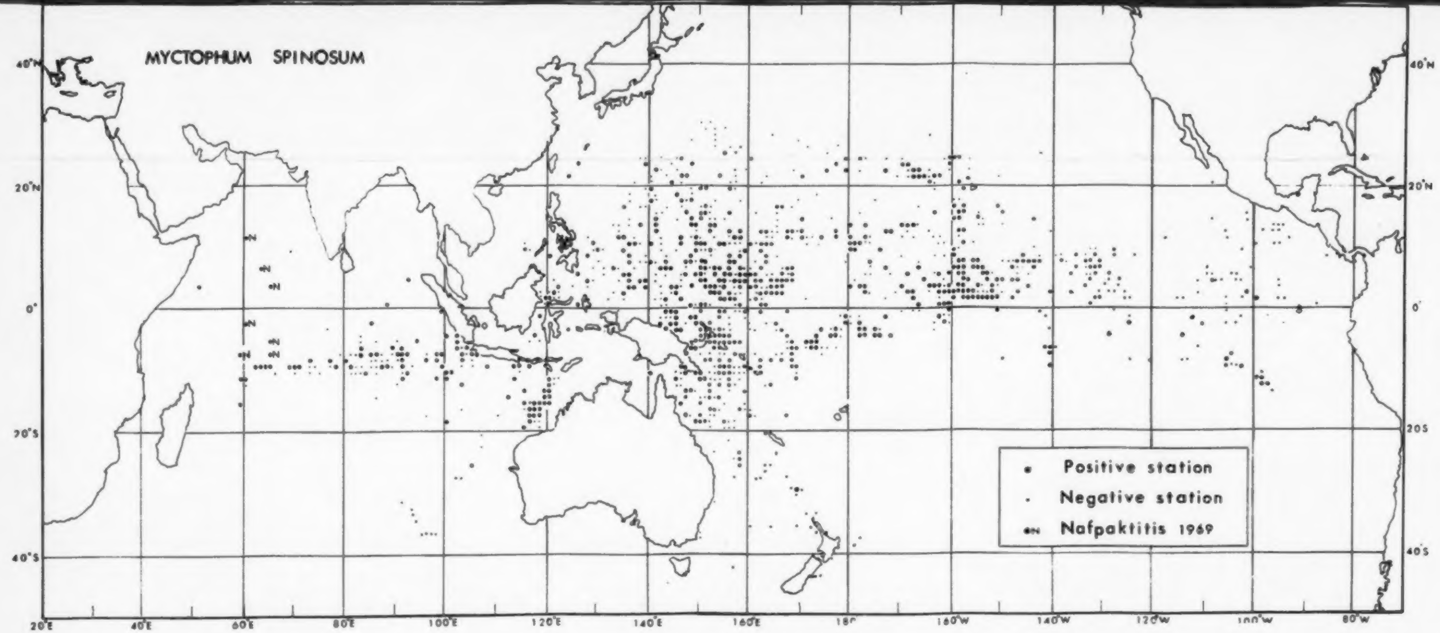
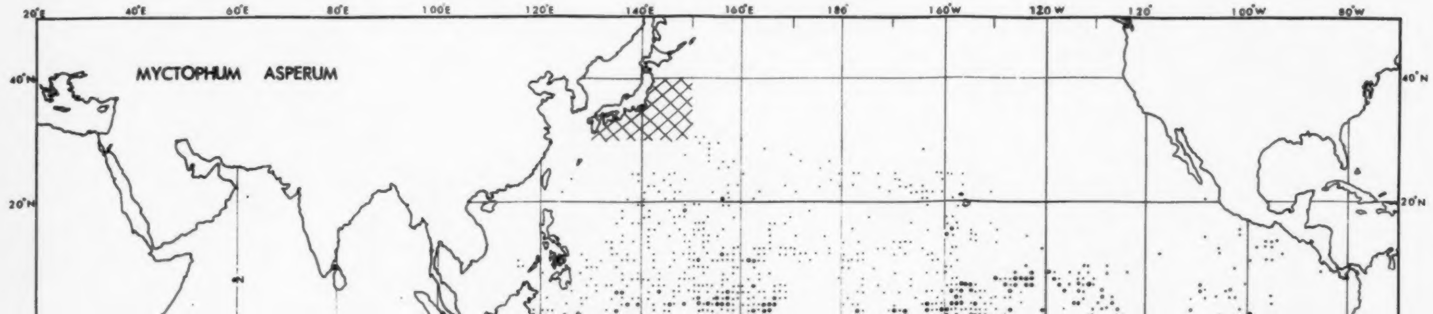


FIG. 19. Distribution of some myctophid fishes (*Centrobranchus* spp.) in the Indo-Pacific Ocean (Bekker 1966). (1, *C. brevirostris*; 2, *C. choerocephalus*; 3, *C.* sp.; 4, *C. nigro-ocellatus*; 5, North sub-tropical convergence.)


MYCTOPHUM OBTUSIROSTRUM
Positive station
Negative station
Nafpaktitis 1969
20°E
40°E
60°E
80°E
100°E
120°E
140°E
160°E
180
160°W
140°W
120°W
100°W
80°W
40°N
20°N
0°
20°S
40°S


MYCTOPHUM SPINOSUM
20°E
40°E
60°E
80°E
100°E
120°E
140°E
160°E
180°
160°W
140°W
120°W
100°W
80°W
40°N


MYCTOPHUM SPINOSUM
Positive station
Negative station
Nafpaktitis 1969
40°N
20°N
0°
20°S
40°S
20°E
40°E
60°E
80°E
100°E
120°E
140°E
160°E
180°
160°W
140°W
120°W
100°W
80°W


MYCTOPHUM ASPERUM
40°N
20°N
20°E
40°E
60°E
80°E
100°E
120°E
140°E
160°E
180°
160°W
120 W
120°
100°W
80°W

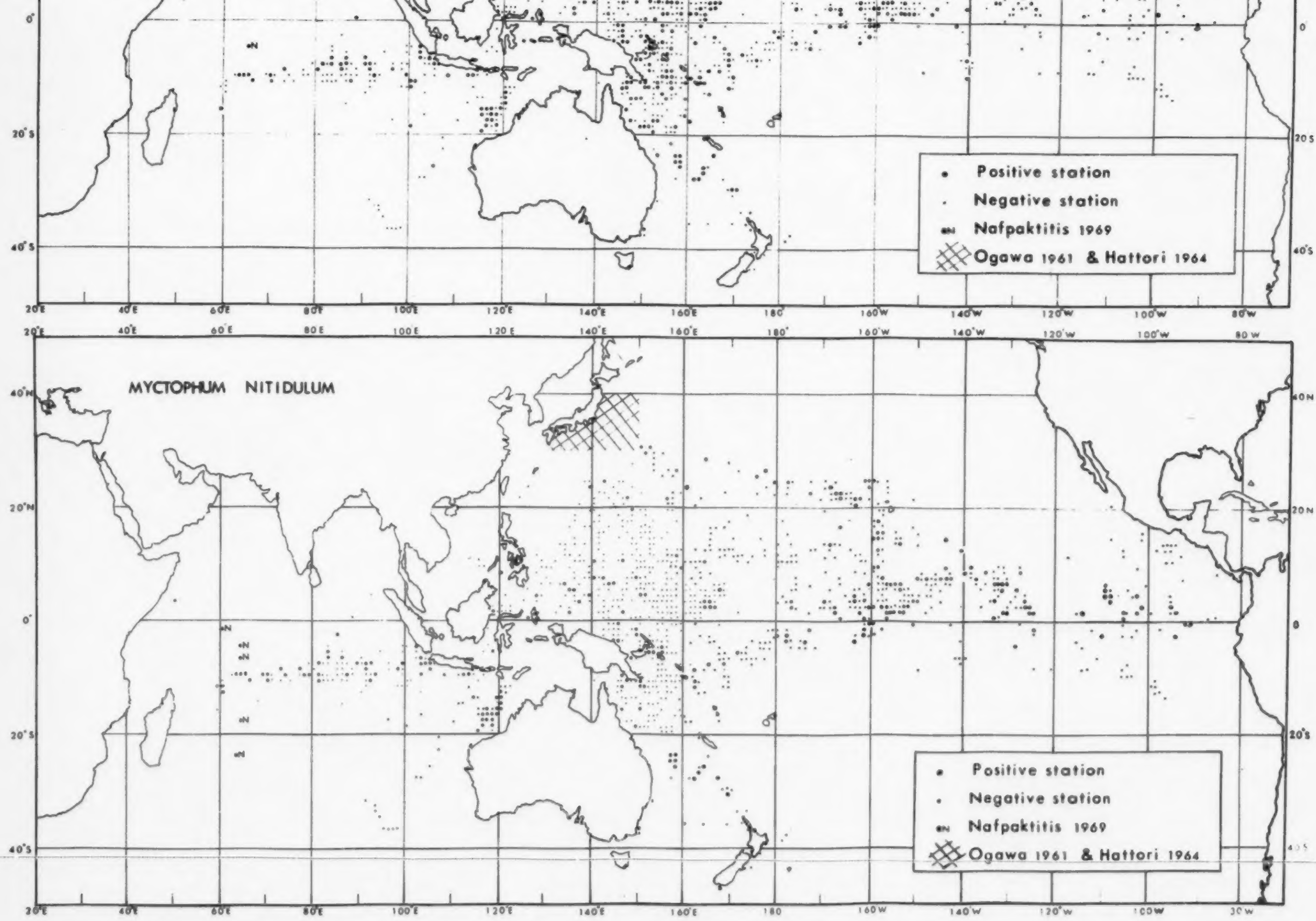

MYCTOPHUM NITIDULUM
Positive station
Negative station
Nafpaktitis 1969
Ogawa 1961 & Hattori 1964
40°N
20°N
0°
20°S
40°S
20°E
40°E
60°E
80°E
100°E
120°E
140°E
160°E
180°
160°W
140°W
120°W
100°W
80°W

FIG. 20. Distribution of myctophid fishes (*Myctophum* spp.) caught by larval net (Kawaguchi et al. 1972).

Data on these fishes are not sufficient to estimate their resources, but for the eastern central Pacific Ocean, where a substantial plankton survey has been carried out, it is thought that 750,000 tons of gonostomatids could be harvested yearly. In the Indian Ocean myctophid and gonostomatid larvae make up a large proportion in the pelagic eggs and larvae sampled.

Demersal Fishes

CAPELIN, SAND LANCE, AND ARGENTINES

These fish have long been caught incidentally by trawls in major commercial fisheries, so they have been fairly well known for a long time. A certain quantity is consumed as food by the Japanese, and recently large quantities have been used in fish farming, especially sand lance. In the other areas of the world, perhaps because of their small size, fish of this group are utilized only for fish meal. However, the fish eggs and larvae taken in high latitudes include significant numbers of these species, which is some indication of their potential. Major species of the group are listed in Table 8.

Capelin (*Mallotus villosus*) — The catch in 1970 was 1.5 million tons. Norway produced 1.3 million tons in 1970 by purse seine, drawing on the Barents Sea stock. The stock has fluctuated widely and is strongly influenced by the fishery (Bakken and Dragesund 1971).

Argentines (*Argentina*) — The catch of Atlantic argentines or silver smelt (*Argentina silus*) in 1970 was 3000 tons, while that of Pacific argentine or deep-sea smelt (*A. semifasciata*) by Japan totalled 17,000 tons.

Sand lances or sandeels (*Ammodytes*) — World catches from 1968 through 1970 were 356,000, 228,000, and 426,000 tons respectively, an average of 337,000 tons per year. Denmark and Japan catch most of these fish.

TABLE 8. By-product species in conventional demersal fisheries in high latitude waters.

Location	Species
Capelin (caplin)	
N Atlantic	*Mallotus villosus*
NE Pacific	*Mallotus villosus*
Argentines (silver smelts, silversides)	
NW Atlantic	*Argentina silus*
NE Atlantic	*A. silus* and *A. sphyraena*
SW Pacific	*A. elongata*
Sand lances (sandeels)	
NW Atlantic	*Ammodytes dubius*
NE Atlantic	*A. lanceolatus* and *A. tobianus*
W central Atlantic	*A. americanus*
SE Atlantic	*A. capensis*
W North Pacific	*A. personatus*
E North Pacific	*A. hexapterus*

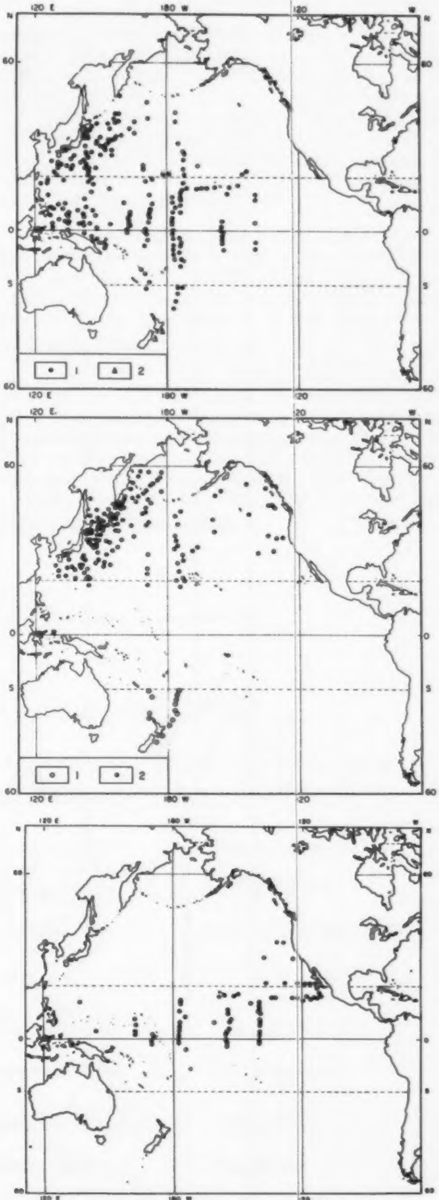


FIG. 21. Distribution of some species of *Cyclothone* in the Pacific Ocean (Mukhacheva 1968) (*Top*): 1, *C. alba*; 2, *C. braueri*; (*Middle*): 1, *C. microdon*; 2, *C. pacifica*; (*Bottom*): *C. acculinidens*.

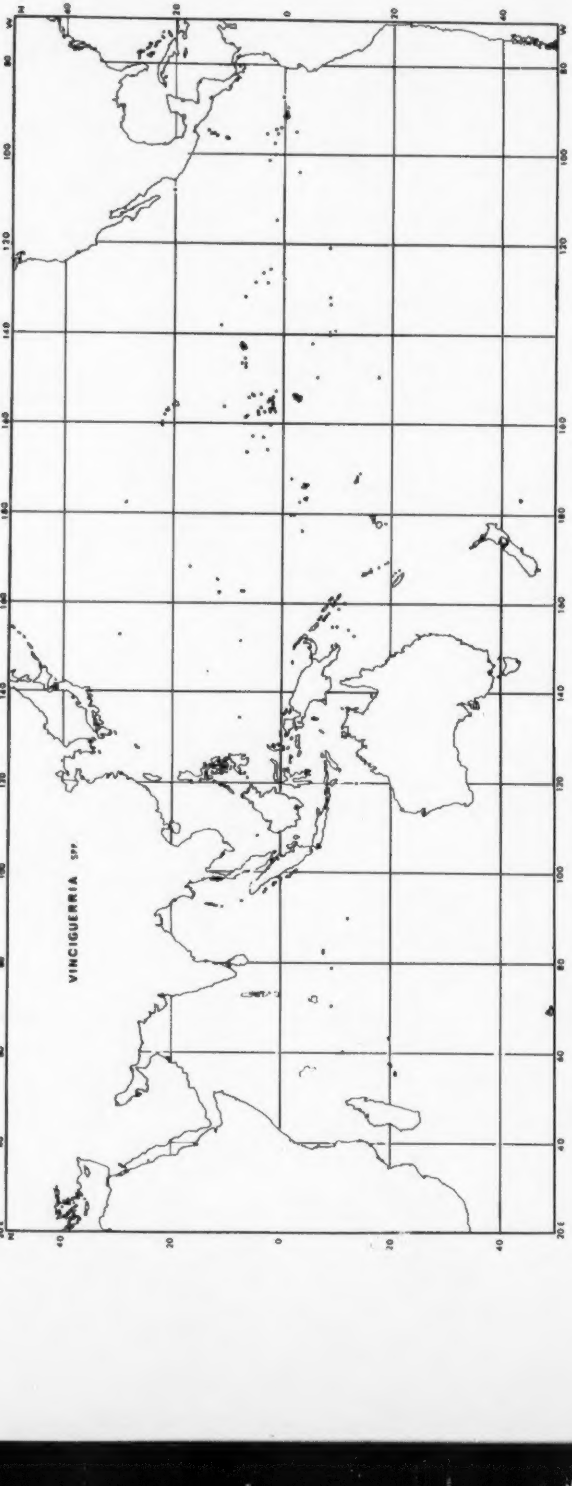

VINCIGUERRIA SPP
20 E
40
60
80
100
120
140
160
180
160
140
120
100
80
60
40
20 W
N
40
20
0
20
40
S

FIG. 22. Distribution of *Vinciguerria* sp. (Ueyanagi et al. 1969).

Capelin was formerly only a by-product of trawling but an intensive purse seine fishery has developed recently. Argentines and sand lances are caught by trawl as a by-product but there appears to be no problem regarding techniques of harvesting them if it is decided to utilize this resource. The problem is to develop a market.

Possible future catches of these three fishes are as follows:

Capelin

Northwest Atlantic: 500,000 tons.

Northeast Atlantic: Norway caught 1.3 million tons in 1970 so the stock is no longer regarded as non-conventional.

Northeast Pacific: No estimate available.

Argentines

Northwest Atlantic: 50,000 tons.

Northeast Atlantic: 100,000 tons.

Southwest Pacific: No estimate available, but experimental trawling indicates possibilities for development.

Sand lances

Northwest Atlantic: Larvae are abundant; possible catch is several hundred thousand tons.

Northeast Atlantic: 300,000 tons.

West central Atlantic: 100,000 tons.

Southeast Atlantic: 50,000 tons.

Northeast Pacific: Latent resources are indicated but no concrete information is available to make an assessment.

HAKES AND POUTASSOUS (*Merluccius and Micromesistius*)

Hakes and poutassous form part of the resources on the slope of the continental shelf. Hakes occur on the shelves and the outer slopes in both hemispheres, down as deep as 1000 m. The major stocks are listed in Table 9, and their distribution is shown in Fig. 23. There are six species of hake found along the eastern coast of the Atlantic Ocean, four along the western coast of the Atlantic, four along the Pacific coast of the American continent, and one species near New Zealand.

The European, silver, Cape, Patagonian, Chilean, and North Pacific hakes have been utilized commercially. It is likely that only the Chilean and Patagonian hakes can be utilized to a significantly greater extent. Australian hake may also have potential as they have been little utilized to date.

The poutassous (blue whiting and southern blue whiting) are also promising. The poutassou (*Micromesistius poutassou*) is exploited in the northeastern part of the Atlantic, 38,000 tons having been caught in 1970. The southern blue whiting (*M. australis*), occurs off southern South America and in New Zealand and Australian waters. Both stocks of southern blue whiting appear to be very abundant.

TABLE 9. Major stocks of hakes (*Merluccius*).

Scientific name	English name	Catch in 1970 by major fishing nations (*thousand tons*)
Eastern coast of the Atlantic Ocean		
Merluccius merluccius	European hake	145 (Spain, France)
M. cadenati	Mauritanian hake	15 (Portugal)
M. senegalensis	Senegalese hake	
M. poli	Cape hake	663 (USSR, Spain)
M. paradoxus		
M. capensis		
Western coast of the Atlantic Ocean		
M. albidus		
M. bilinearis	Silver hake	222 (USSR, USA)
M. magnoculus		
M. hubbsi	Patagonian hake	100 (Argentina)
Western coast of the American continent		
M. productus	North Pacific hake	171 (USSR)
M. angustimanus		
M. gayi	Chilean hake	105 (Chile)
M. polylepis		
Waters of Australia and New Zealand		
M. australis	Australian hake	

Patagonian area — Zenkevich and Sauskan (1968) reported that the stock of Patagonian hake is distributed between 35°S and 45°S. A remarkable concentration occurs during the southern winter (May–August) north to 40°S at depths from 70 to 170 m. During September to November the schools move to the area south of 40°S, at depths between 60 and 80 m. This is their feeding season, during which they disperse over a wide area. The months from December to February are the spawning season and dense concentrations occur at depths from 400 to 500 m. In April the fish start their northern migration. Fish from 35 to 55 cm long are most frequently caught in trawls. The estimated possible catch is 1.2 million tons a year, as compared with recent catches of about 100,000 tons.

Chilean area — About 100,000 tons a year of Chilean hake are caught. The domain of this fish runs from 5°S to probably 40°S. A recent study suggests that it is intensively exploited off Chile, but that certain parts of the stock, especially that off Peru, are not exploited fully. A recent estimate of sustainable catch is 200,000 tons, of which 100,000 tons are already being taken.

Australian and New Zealand area — Australian hake and southern blue whiting on the slope off the continental shelf of New Zealand are not yet utilized on a substantial scale. Though further data are necessary to estimate the sustainable yield of these stocks, an extension of the fishing area seems possible and there may be a large potential for increasing the catch.

GRENADIERS AND MORIDS (*Macruridae* AND *Moridae*)

Macrurids are bathyal and abyssal fishes that inhabit the outside slope of the continental shelf and the basins of oceans, down to 3000–4000 m. About 300 species have been described. Different species occur in different parts of the ocean and the total area occupied by this group is extensive. These fish often form dense schools. They have not been utilized except by Japan and the USSR.

Morids are somewhat similar to macrurids in occurrence. *Physiculus bachus* of the southwest Pacific area is the best known species. They are found on the continental slope and in the basins of the ocean, at somewhat shallower depths than macrurids.

Several of these species appear to be worth considering for utilization (Table 10).

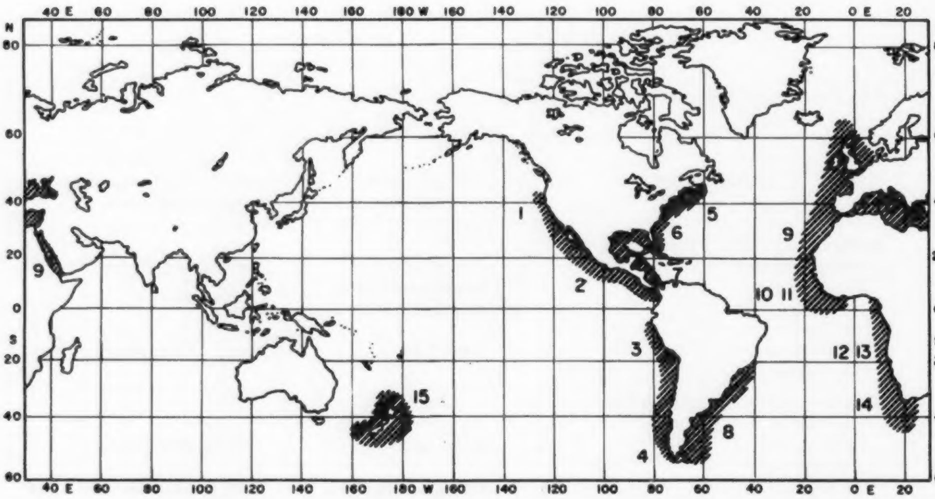


FIG. 23. Major stocks of hake (*Merluccius*) in the world ocean (Sauskan 1966). (1, *M. productus*; 2, *M. angustimanus*; 3, *M. gayi*; 4, *M. polylepis*; 5, *M. bilinearis*; 6, *M. albidus*; 7, *M. magnoculus*; 8, *M. hubbsi*; 9, *M. merluccius*; 10, *M. cadenati*; 11, *M. senegalensis*; 12, *M. poli*; 13, *M. paradoxus*; 14, *M. capensis*; 15, *M. australis*.)

TABLE 10. Important species of macrurids and morids.

Local name	Scientific name
North Pacific	
Mune-dara	*Nematonurus pectoralis*
Ibarahige	*N. acrolepis*
Karafuto-sokodara	*Coryphaenoides cinereus*
ICNAF area (NW Atlantic)	
Roundhead grenadier	*Macrurus* (*Coryphaenoides*) *rupestris M. berglax*
Chilean waters	
Grenadier	*Macruronus magellanicus*
New Zealand waters	
Red cod	*Physiculus bachus*

Macrurids of the North Pacific Ocean — Of three common species, *Nematonurus pectoralis* is the most abundant. *Nematonurus* are large, averaging 70–90 cm and 3–5 kg, while *Coryphaenoides cinereus* averages only 40–50 cm and 0.1–0.2 kg. These species form the major component of the catch from the outer slope of the continental shelf.

The biology and ecology of *Chalinura pectoralis* (probably a synonym of *Nematonurus pectoralis*) are described by Novikov (1970). The species occurs over an extensive area of the slope of the continental shelf (Fig. 24). Young fish less than 20 cm occur throughout a wide vertical range. They may live a long time, probably 15–17 years. Fish of 6–11 years compose the major part of the trawl catch. The species grows quickly and attains 63–68 cm in the first 6 years, but subsequently the growth rate falls off and during the next 6 years they only grow another 17–20 cm. They feed on small fishes, molluscs, crustaceans, and other benthos. They migrate little, and during winter and early spring stay deep (650–800 m). In summer they range from 400 to 1000 m. The most remarkable concentrations observed have been on the slopes of a bank in the central and northwestern Bering Sea (Fig. 24). It is estimated that a catch of more than 100,000 tons could be reasonably expected from this underutilized resource (Gulland 1972).

North Atlantic macrurids — The combined catch of several species is expected to be 50,000 tons. The roundhead grenadier (*M. rupestris*) is at present being mainly exploited by the USSR (ICNAF Report). *Macrurus berglax* is thought to occur in large quantities at 320–360 m in the Labrador area and is expected to yield a catch of about 50,000 tons.

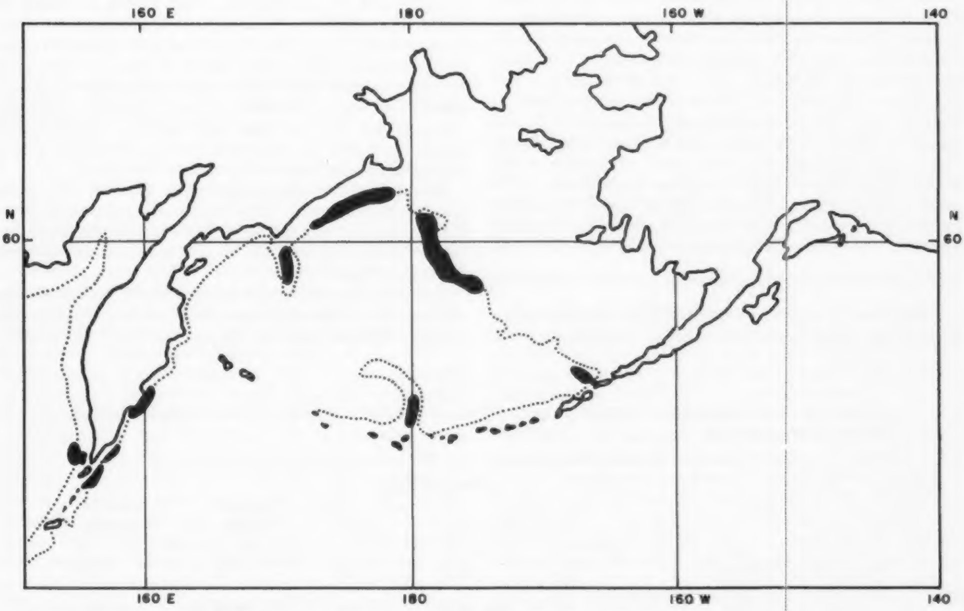


FIG. 24. Distribution of *Chalinura pectoralis* in the north Pacific Ocean (Novikov 1970).

Chilean grenadiers — The "merluza de cola" is the dominant species in the area south of 43°S, as indicated by experimental trawling. The catch of this species diminishes significantly north of 43°S. The average fish taken is about 40 cm long and 500 g in weight (Fishery Agency of Japan 1969).

New Zealand red cod — *Physiculus bachus* occurs on the slope of the continental shelf around New Zealand, usually not deeper than 400 m. This species attains a length of 80 cm. It is carnivorous, living on small fishes, crustaceans, and molluscs, with a special taste for crustaceans.

NOTOTHENIDS (NOTOTHENIIDAE)

More than 10 species are included in this group, distributed widely on the continental shelves of Patagonia and Antarctica, and on their outside slopes. They are found between 100 and 400 m. The largest catch is expected to be from the stock of *Notothenia ramsayi*, although *Notothenia squamiformis* is also important. The fish school and are caught by trawling. The average size taken is 30–40 cm. They feed on small crustaceans and other benthos. Quantitative information is not available since there is no substantial commercial fishery, but the limited spawning area in the Antarctic Sea suggests that the stock is not large.

FISHES OF THE TROPICAL CONTINENTAL SHELVES

A characteristic of the demersal fishes on the continental shelves in tropical areas is the multiplicity of species. The dominant ones are usually small and of little market value. Snappers, groupers, butterfish, and croakers are the species of higher value, but their catch is not significant. The estimates of FAO's Perspective Study of World Agricultural Development (Gulland 1972) and those based on recent actual catches (Table 11) indicate that a very big increase in the catch is possible in the Indian Ocean and the Indo-Australian Archipelago. However, the greater part of this potential probably consists of species of little commercial value. The important demersal species in the catch in Indian waters are listed in Table 12.

RESOURCES OF GUYOTS (SEAMOUNTS) AND OCEANIC BANKS

In temperate waters two species have achieved some commercial importance, the boarfish, *Quinquarius japonicus*, and the berycoid species *Beryx splendens*. Since 1967 the USSR has been taking these species on the northwestern part of the Hawaiian ridge, using trawls. Japan entered the area later and now takes 30,000–50,000 tons a year. Present trawling grounds in the temperate portion of the North Pacific Ocean are on guyots. These are isolated from each other, and depths vary from 160 to 400 m. Some boarfish have been caught in the surface layer of the North Pacific north of 40°N by hand line and some by gillnet. It is reported that sei whales eat large quantities of boarfish and berycoids in this area. These species have also been reported from various parts of the southern hemisphere. They do not seem to be present in tropical waters, so that the southern and northern groups are isolated.

The spawning grounds of the boarfish are unknown. Chikuni (1970) believes that it is distributed over the northern hemisphere between 15 and 55°N, in the North Equatorial, North Pacific, California, and Alaskan currents. He infers that it is a bottom dweller in temperate waters south of 40°N, concentrated on the tops of guyots, but pelagic over the oceanic area north of 40°N.

The fish caught by trawl average about 30 cm in fork length and are believed to be 5–7 years old. On the basis of information provided by Russian scientists Sakiura (1972) has stated that the species performs distinctive diurnal vertical migrations. During the daytime the schools go upward to feed, and occupy the space from the bottom to the middle layers; at night they are again concentrated on the bottom. Thus fishing is easiest at night. The stock can be depressed by fishing where the bottom is flat, but as this is not always the case on guyots the fishing gear cannot take the whole stock. Further, the trawlnet cannot take the young fish because they are above the bottom. However, since guyots are not extensive and the resource does not appear to be large, the stock can readily be depressed to a level yielding a low economic return even if it cannot be fished out.

Berycoid fishes are caught with boarfish and their distribution is similar. They are found at depths of from 300 to 800 m. They appear to prefer a little higher water temperature than boarfish. Their average size in the trawl catches is about 35 cm.

The resources of tropical oceanic banks include sharks and various species of *Lutianus* and *Lethrinus*. An example of such resource areas is the coral bank of the western

TABLE 11. Possible catch of tropical demersal fishes in thousands of metric tons, and rate of catch in kilograms per hour.

Area	Possible catch		Present catch	Possible increase
	Quantity	Rate		
West coast of Africa	300	12	170	130
Caribbean Sea and northern coast of South America	150–500	3–11	100(?)	50–400
Indian Ocean	7500	27	700	6800
Indo-Australian Archipelago	7000–10,900	19–30	2500	4500–6400
Pacific coast of Central America	1000	(30)	200–500	500–800

TABLE 12. Major species of demersal fishes in Indian waters.

A. Dominant species from conventional fishing grounds (after Jones 1966)

Bombay duck	*Harpodon nehereus*
Sharks	About 12 species
Sciaenids	More than 10 species
Silverbellies	*Leiognathus splendens* and several other species
Pomfret	3 species
Catfishes	Several species
Big-jawed jumper	*Lactarius lactarius*
Eels	*Muraenesox talabonoides* and *M. cinereus*
Threadfins	*Eleutheronema tetradachylum* and two other species

B. Species of potentially useful stocks outside conventional fishing grounds (after Hayasi 1971)

75–100 m
- *Nemipterus japonicus* (dominant)
- *Trichiurus lepturus*
- *Decapterus russelli*
- *Penaeus indicus*
- *Saurida undosquamis*
- *Synodus* sp.

100–180 m
- *Nemipterus japonicus* (dominant)
- *Synodus indicus* (dominant)
- *Centropristes investigatoris*
- *Emmelichthys* sp.
- *Priacanthus* sp.
- *Callionymus* sp.
- *Peristedion* spp.
- *Trigia* spp.
- *Holocentrus* sp.
- *Polymixia nobilis*
- *Parascolopsis* sp.

180–450 m
Nearly 150 species have been identified

Indian Ocean. Assessments of its potential vary from 100,000 to 250,000 tons. This kind of bank is often rough, which makes trawling difficult.

Cephalopods

The recent world catch of cephalopods is about 1.2 million tons, of which 900,000 tons are squids, 60,000 tons cuttlefishes, and 190,000 tons octopus. The high nutritive value and recent level of consumption of squids are described by Idyll (1968). A stable market for squids, cuttlefish, and octopus as human food has not yet been established except in the Mediterranean and the Far East. There is also some demand for them for use as fishing bait in several parts of the world. Thus the present total demand cannot support a large scale fishing effort.

Cephalopods include about 500 species but their biology and ecology are little known. Squids seem to form a staple diet of carnivorous fish, marine mammals and sea birds. For example, they form about 30% of the stomach contents of tunas and marlins caught in oceanic areas. The world catch of large tunas is about 850,000 tons, and the standing crop which can support this annual harvest is at least 1.5 million tons. If the ecological efficiency factor is 15%, these tunas devour some 3 million tons of squids each year. In Japan, where fisheries for squids and cuttlefish are well developed, the catch is about 500,000 tons a year — a substantial part of the catch of pelagic species, as shown in the schedule below:

Year	Horse-mackerels and scads	Mackerels	Squids	Total	*Squids* Total
1966	514	624	485	1623	30%
1967	423	687	597	1707	35%
1968	358	1015	774	2147	36%
1969	341	1011	590	1942	30%
Average			611	1855	33%

The natural food of these animals consists of macroplankton and small fishes. They are probably at the same trophic level as mackerel, or a little higher. They are active and play an important role in distributing organic material from more fertile to less fertile areas.

Three-quarters of the world squid catch is of species in the family Todarodidae. The rest consists of loligiform squids (Loliginidae) and cuttlefishes (Sepioidae). The family Todarodidae includes 17 species (Table 13), many of them migratory on the high seas (Fig. 25). When fully grown, they are to be found from the surface to a depth of several hundred meters. Their mantle length usually ranges from 15 to 30 cm, although some grow to an extraordinarily large size. Experimental fishing and information from fishermen suggest a very large resource. The catch of *Todarodes pacificus*, shown in Table 13, suggests that a potential catch of some hundreds of thousands of tons from other todarodid species may be possible.

TABLE 13. List of todarodid squids from world oceans (prepared by T. Okutani). Items marked by an asterisk are known to be abundant.

Species	Maximum mantle length in cm	Area of occurrence	Fisheries
*Illex illecebrosus**	25–28	Northern part of the Atlantic (continental shelf and slope)	Newfoundland, 11,000 tons by jig, mostly for bait
*Illex coindeti**	25	Atlantic Ocean	Gulf of Guinea on a small scale
Todaropsis eblance	27 (female)	as above	–
Todarodes sagittatus	47 (female)	Atlantic and Indian Oceans	Lofoten Islands (Norway) The catch was 9600 tons in 1956, used for bait in cod and halibut fisheries
*Todarodes pacificus**	36	Waters adjacent to Japan	Japan, 500,000 tons by jig, trawl, and trapnet
*Nototodarus sloani sloani**	36	Waters adjacent to New Zealand	Fished by the Japanese fleet
N. sloani gouldi	(120 cm total length)	Australia	–
N. sloani philippinensis	18	Philippines	–
*N. sloani hawaiiensis**	15	Hawaii	–
Symplectoteuthis ovalaniensis	31	Temperate and tropical Indo-Pacific area	–
S. luminosa	18 (female)	North Pacific Ocean	–
*Dosiducus gigas**	(350 cm total length)	Pacific coast of North and South America and Australia	–
Ommastrephes bartrami	36	Pacific Ocean	–
O. calori	61	Northeastern coast of the Atlantic and Mediterranean	Catch fairly large, used for human consumption and for bait
O. pteropus	38	South Atlantic and Caribbean Sea	
O. argentinus	25	Atlantic coast of South America	–

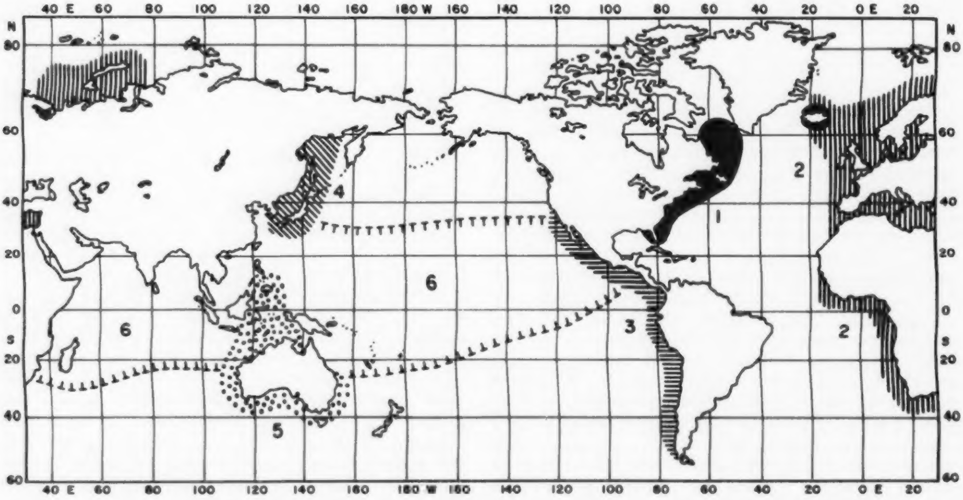


FIG. 25. Distribution of todarodid squids in the world ocean (prepared by Okutani, Tokai Reg. Fish. Res. Lab., Tokyo on the basis of data prepared by Clarke (1966)(1, *Illex illecebrosus*; 2, *Todarodes sagittatus*; 3, *Docidicus gigas*; 4, *Todarodes pacificus*; 5, *Nototodarus gouldi*; 6, *Symplectoteuthis ovalaniensis*.)

Squids are sometimes captured by purse seine when they concentrate at the surface. However, the commonest way of catching them is by jigging. Trapnets and various kinds of small seines are also used, depending on local conditions.

Onychoteuthis banski and *Thysanoteuthis rhombus* are species of wide distribution in the offshore area. This wide occurrence indicates a large population, but the schools are scattered.

Loligiform squids and cuttlefishes are coastal, and their biomass may not be particularly large. They occur sporadically and probably can support only local fisheries. Generally speaking they yield better quality meat and so fetch a higher price than todarodids.

Estimates of possible increases in catch of cephalopods (Perspective Study of World Agricultural Development) are as follows, in thousands of metric tons:

Atlantic Ocean		*Pacific Ocean*	
Northwestern	300	Northwestern	100
Northeastern	1000	Northeastern	300
Eastern central	300–650	Eastern central	600
Western central	500–1000	Western central	?
Southwestern	500	Southwestern	?
Southeastern	300	Southeastern	500

Indian Ocean	
Whole	300

The total is 4,700,000 to 5,500,000 tons.

Prospects for Future Development

COASTAL PELAGIC FISHES

Clupeoids, horsemackerels, scads, and mackerels are carnivores with similar feeding habits, and occur in similar areas. This makes it possible to catch them with the same fleets and by similar fishing methods. They are all on a low trophic level, and nets are the principal gears used to capture them. These coastal pelagic resources support profitable fisheries, and they have been exploited for a long time in spite of large yearly fluctuations.

Anchovies are a less valuable resource than some others in this category, and in many places are still underexploited. Horsemackerels and scads are also in less demand as food so that they have not been as intensely exploited. An assessment of the potential increase of catch from the coastal pelagic resources are summarized by area in Table 14. Anchovies constitute a major part of the latent resources in the northern hemisphere. In the southern hemisphere anchovies are again the major component of the potential resources, with herring, mackerel, and horsemackerel as additional elements. The fact that the major fishing countries are located mainly in the northern hemisphere is one reason why valuable resources in the southern hemisphere have been unexploited.

In tropical areas fisheries are not always successfully developed, even though the potential resource is large. Sporadic occurrence of species, the large number of species, and their small size, discourage exploitation. There are also problems involved in developing markets in tropical areas, and difficulties in introducing modern fishing and marketing techniques. Tiews (1966) has pointed out the problems for demersal fisheries in the Indo-Pacific Fisheries Commission area.

OCEANIC PELAGIC FISHES

Flyingfishes and sauries are first-stage carnivores, and occupy the third trophic level. Rainbow runners and

TABLE 14. Possible increases in catch from coastal pelagic resources, in thousands of metric tons.

Temperate and cold waters, northern hemisphere	
Western North Atlantic	
Anchovy	600
Eastern North Atlantic	
Anchovy	700
Californian coast	
Northern anchovy	1000–2000
Pacific jack mackerel	300–800
Pacific mackerel	40
Temperate and cold waters, southern hemisphere	
Western South Atlantic	
Falkland herring	1000
Argentine anchovy	750
Mackerel	Unknown
Eastern South Pacific	
Chilean horse mackerel and mackerel	100
Australian and New Zealand waters	
Australian pilchard and anchovy	100
Horsemackerel	50
Mackerel	Unknown
Eastern South Atlantic	
Cape anchovy	250
Maasbanker	600
Round and flat sardines	700
Round herring	300
Tropical waters	
Gulf of Mexico and Caribbean Sea	
Anchovies, Venezuelan sardine, thread herring	1500–2000
Western coast of Central America	
Sardinella and anchovies	200
Horsemackerel and mackerel	100–400
Pacific coast of Central America	
Anchovies and thread herring	700–1650
Western tropical Pacific, Indo-Australian Archipelago and Arabian Sea	
Anchovies and thread herring	Unknown
Oil sardine (Arabian Sea)	Unknown
Scads and Indian mackerel	> 500
Spotted mackerel (South China Sea)	200–400
Potential increase, combined species:	
Whole Indian Ocean	5000
Whole western central Pacific	1000–5000

dolphinfish are at the second stage, and small tunas are at the highest step in the food chain. Therefore, these fish have to be caught with a variety of gears. Flyingfishes and sauries are taken by nets, while other species are caught by hook-and-line gear. When oceanographic conditions favor the formation of surface schools, nets are effective even for tunas.

All these species are widely scattered over the high seas, which increases the difficulty and the cost of catching them. At present they are not utilized on a commercial basis, except for the large tunas (yellowfin, albacore, bigeye, and bluefin). The present difficulty is to find efficient means of exploiting such widely scattered species, especially those at the higher trophic levels. For sauries and probably for flyingfishes, light appears to be effective in concentrating schools at the surface. In view of this, a profitable offshore fishery could be established with this resource, with an estimated catch of more than a million tons. There are reports from fishermen that the rainbow runner similarly responds to lights, but there is no such indication concerning other pelagic species.

The small tunas — skipjack, black skipjack, frigate mackerel, blackfin tuna, longtail tuna, and bonito — may be promising species for the future because of a growing demand in world markets. Hooking gear may be the principal method for catching them, but here again the fish, except for skipjack, do not lend themselves to exploitation on a large scale because they are found in small local groups. When they school it is usually in coastal areas. In view of these factors, they are most likely to be exploited by small local fisheries where sufficient demand can be developed. Generally speaking Southeast Asia, the easternmost part of the tropical Pacific, and the Caribbean Sea are the centers of concentration of these small-sized tunas. Little is known about the biology of these fish and research is necessary to establish a program for fisheries development. This should include a survey of the live-bait available for the development of pole-and-line fisheries since bait supply is the limiting factor in such a development.

OCEANIC MESOPELAGIC FISHES

The utilization of myctophids and gonostomatids is small because they are found in deep offshore waters and then only in small schools. It has been reported that during the daytime one of the myctophids (*Ceratoscopelus maderensis*) concentrates in the deep layer (Backus 1968). Perhaps the problem of exploiting these stocks could be solved by studying their schooling habits. As the fish are of small size and appear to be inferior as food, they will probably be utilized for fish meal, as is done now with occasional catches of myctophids in South Africa. Costs of fishing and market prices need to be ascertained to establish the economic viability of such a fishery. If it were found to be worthwhile, it might be substantially different in nature to that of the conventional fisheries and would probably require powerful, highly mechanized vessels of great mobility.

DEMERSAL FISHES

Demersal fish are effectively caught by trawling and most resources are already heavily exploited, so the potential for increase is not great. One potential resource consists of by-product species from conventional fishing grounds, usually those without present market value Unless a demand for such species is created, they will remain unused. If a demand is developed, exploitation quickly follows. An example is the development of the capelin fishery in the ICES area during the last 2 or 3 years. Another example is the huge utilization of sand lance in rearing yellowtail in Japan.

Resources on the slope of the continental shelf in temperate waters are second-stage carnivores. They are deep-sea dwellers but recent developments in fishing gear are such that deep-sea resources can be successfully exploited. There is a need to know much more about the macrurids in order to establish fisheries for them.

The problems of exploiting the resources of the tropical continental shelf and of the oceanic ridges and banks were discussed earlier.

CONCLUSION

A summary of assessments of possible increase in catches from the various demersal resources of the world is given in Table 15. As can be seen, there are few latent resources of commercial value in the northern hemisphere, except by-product species. There is little room for the immediate expansion of demersal fisheries here. In the southern hemisphere the possible increase in catch is calculated at more than 2 million tons. It is interesting to note that the estimated catches of sand lance, macrurids, and argentines in the southern hemisphere are less than those in the northern hemisphere. This may be because of lack of information due to the lower level of fishing activity in the southern hemisphere, so the potential catch

TABLE 15. Possible increase in catch from demersal resources, in thousands of tons.

By-products from conventional fisheries in the northern hemisphere	
Capelin	500
Sand lance	900
Argentine	150
Resources on the continental slope in the northern hemisphere	
Macrurids and morids	150
Guyot fishes	50
Resources of the continental slope in the southern hemisphere	
Sand lance	50
Hake and poutassou	1700–2200
Macrurids and morids	?
Notothenids	?
Guyot fishes	50
Resources in tropical waters	11,980–14,530
Grand total	15,530–18,580

is probably underestimated. In addition to species of wide distribution there may be local stocks in the southern hemisphere of the kind which are already heavily utilized in the northern hemisphere.

The potential increase in catch from the tropical areas of the Indian Ocean and Indo-Australian Archipelago is thought to be more than 10 million tons, while that of the tropical Atlantic is considered small. However, as already pointed out, the exploitation of tropical resources usually presents a number of difficulties and the establishment of any large scale fishery may not be workable in these areas. Tiews (1966) referred to this problem in the fishery in the Gulf of Thailand as follows: "The reason for the late development of the trawl fishery in the region is largely due to the failure of several previous attempts to introduce this type of fishery owing to the use of unsuitable fishing vessels and fishing gear . . . From its very beginning, the Thai trawl fishery has been carried by small fishing boats . . . [which] fish with very light fishing nets . . . Since the size of the fishing unit has been adjusted in accordance with the density of fish stock, [these] are able to carry out trawl fishery with great economic success."

The basis of development of a fishery in a tropical area is an ability to cope with the biological features of the resources with a suitable fishing method, and marketing on a scale sufficient to make investment profitable.

Future Problems

Two outstanding problems concerning the development of fisheries require research and development effort: the delay in mounting the exploitation of resources on the continental shelf in tropical waters, and the development of new fishery products. Delayed exploitation raises such questions as: why fishery interests have not been attracted to the resources and, of course, how to utilize the resources. These are not questions to be answered by this paper but the observations by Tiews, already referred to, seem pertinent.

Use of Marine Animals Other Than as Food

Regarding the problem of the use of marine animals other than as food, two questions are involved. The first concerns the development of fishing techniques for exploitation of resources which are scattered. To cope with this, more surveys and studies of the ecology of the species involved are necessary in order to develop the appropriate fishing gear and tactics. The other question concerns the effects of extensive and intensive exploitation of resources at lower trophic levels on the productivity of fish at higher levels in the food chain. A newly developed fishery may intensify the harvest of creatures at an earlier stage of the food chain, thereby affecting dependent stocks. Some of the larger fish which are directly consumed by man would probably suffer. What is needed, therefore, is a study on how to achieve rational utilization of the whole productive system of the ocean rather than maximum sustained yield of individual resources.

The catch from the lower trophic levels will be utilized in various ways, sometimes as fresh fish, but mostly for fish meal. Schaefer and Alverson (1968) say that 40% of world fish production today is processed to make meal and oil. The meal is used as a protein food supplement for poultry, cattle, pigs, and fish, but the recovery of protein through domestic animals is only about 10–15%. If eaten by mankind, the marine resources can provide more protein, so every effort should be made to process fish and other aquatic species for consumption directly by mankind. Fish paste is an excellent example, if only because it can be transported all over the world.

Variety of Demand for Marine Products

Another problem is the variety of demand for marine products, often based on local food preferences. The demand for marine products, therefore, is quite diversified. Tunas provide an example. In North America and Europe people consume much canned tuna and its market is growing yearly, but the Japanese, by contrast, prefer fresh meat, *sashimi*. The better material for sashimi comes from well grown fish, whereas young tuna provide better material for canning. Thus even within the utilization of the same species there are different interests in respect to harvesting. Another example is the difficulty of fully effective conservation of halibut in Icelandic waters in relation to other fishing interests (Gulland 1961). To some extent the young halibut are taken with the main catches of cod, redfish, etc., which are more important than halibut in Iceland.

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The Transition From Small-Scale to Large-Scale Industry[1]

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The transition in fisheries from small-scale to large-scale industry has traditionally evolved in the technically advanced countries over a period covering several generations. The present sophisticated, capital-intensive, highly mechanized fishing industry of Western Europe is a good example of this process.

However, the developing countries of today are not content to wait through the evolutionary period. They want to establish a modern fishing industry — all aspects from catching the fish to processing and consumption — in the shortest time. Some have done so, at least in part, despite difficulties such as lack of trained personnel at all levels, lack of or inadequate infrastructure and marketing and distribution systems, inadequate capital resources, and so on.

The author examines the main problems and challenges of the situation and provides various proposals and guidelines for such rapid development. He points out that the characteristic artisanal fisheries of the developing countries cannot be so transformed into modernized fisheries. They need a separate, slowly developing program for their upgrading. However, they are likely to be stimulated by and benefit from the establishment of a modern capital-intensive industry with which they must coexist. In particular, the artisanal fishermen should benefit from expansion of markets, introduction of new processing facilities, improvements in infrastructure, establishment of higher standards in handling, storage, and processing of fish, perhaps even by injection of capital and being given a specific share of the new industry, such as supplying it with high-priced prime fish, etc.

Dans le domaine des pêches, le passage de la petite à la grande entreprise a généralement demandé, dans les pays techniquement avancés plusieurs générations. L'actuelle industrie halieutique de l'Europe occidentale — très modernisée, exigeant beaucoup de capitaux et hautement mécanisé — est un bon exemple de ce processus.

Toutefois, les pays en voie de développement ne veulent plus aujourd'hui attendre si longtemps. Ils désirent établir aussi rapidement que possible une industrie moderne de la pêche — allant de la capture des poissons à leur transformation et à leur consommation. Quelques-uns l'ont fait, en partie tout au moins, en dépit de difficultés telles que le manque de personnel qualifié à tous les niveaux, l'absence d'infrastructure et de réseaux de commercialisation et de distribution, l'insuffisance des ressources financières, etc.

L'auteur examine les principaux problèmes liés à cette situation et formule diverses propositions et directives en vue d'un tel développement rapide. Il souligne que les pêcheries artisanales typiques des pays en voie de développement ne peuvent se transformer en pêcheries modernes. Leur expansion exige un programme distinct de développement progressif. Toutefois, elles peuvent être stimulées et favorisées par l'établissement d'une industrie capitalistique moderne avec laquelle elles doivent coexister. En particulier, l'artisan-pêcheur devrait profiter de l'élargissement des marchés, de l'introduction de nouvelles installations de transformation, de l'amélioration de l'infrastructure, de l'application de normes plus rigoureuses dans la manutention, l'entreposage et la transformation du poisson, peut-être même grâce à l'injection de capitaux et en participant dans une mesure déterminée aux activités de la nouvelle industrie à laquelle il pourrait par exemple fournir des poissons très recherchés de haute valeur, etc.

La transición de la industria pesquera pequeña a la grande ha tenido lugar tradicionalmente en los países tecnicamente adelantados, en un período que abarca varias generaciones. La actual industria de la Europa Occidental, compleja, con necesidad de mucho capital y muy mecanizada, constituye un buen ejemplo de este proceso.

Actualmente, los países en desarrollo no se contentan con esperar que pase el período evolutivo. Desean establecer una moderna industria pesquera que abarque todos los aspectos, desde la captura hasta la elabora-

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ción y el consumo en el menor tiempo posible. Algunos de ellos ya lo han hecho, por lo menos en parte, a pesar de dificultades como la falta de personal preparado de todas clases, falta o insuficiencia de infraestructuras de sistemas de mercadeo y distribución, recursos insuficientes de capital, etc.

El autor examina los problemas principales de la situación y hace propuestas para una evolución rápida. En el transcurso de su examen, pone de manifiesto que la pesca artesana caracteristica de los países en desarrollo no puede transformarse en una pesca modernizada. Se necesita un programa distinto, lento, que permita su mejoramiento. No obstante, es probable que reciban estímulo y que se beneficien de la institución de una moderna industria con mucho capital, con la que deben coexistir. En especial, los pescadores artesanos deberían beneficiarse de la ampliación de los mercados, de la introducción de nuevos medios de elaboración, de las mejoras en la infraestructura, de la institución de normas superiores para la manipulación, almacenamiento y elaboración del pescado, quizás, incluso, de una inyección de capital y que se les permita una participación específica en la nueva industria, como sería el suministro de pescado de primera calidad y de alto precio, etc.

COUNTRIES vary so much in the base state of their economies, in resources of all kinds, and in their political and economic philosophies, that what may be true about economic development in one country at one time may not be relevant to another. For instance, the fairly constant process of fisheries evolution as a historical process in western Europe, from relatively small-scale, artisanal beginnings in the late nineteenth century to a sophisticated, modern capital-intensive industry is not relevant to what is happening in the developing countries. The autonomous, organic process of growth in fisheries as it took place in western Europe is too slow to be attractive or helpful to the developing nations, whose objective is accelerated economic development.

Since general economic growth often depends on the efficiency of food production and release of manpower from agriculture, the transformation of fisheries and agriculture must precede general economic growth. In these circumstances the rapid development of fishery resources requires positive steps to promote the desired growth and expansion.

Artisanal Fisheries

Despite many national variations, the features of artisanal industries are fairly well defined. Vessels are small and simple and mostly unpowered. Although nylon nets are in almost universal use, the design and operation of gear follows traditional practices. Marketing systems are rudimentary: the fisherman either sells his fish at the landing point to middlemen or local customers, or processes it by smoking or drying.

The fishermen are usually among the poorest section of the population. In some countries many are not entirely within the cash economy, bartering most of the catch for their living requirements, and rarely handling cash for replacement of gear, etc. There is rarely a surplus for investment in improved vessels and gear, and a high proportion of such fishermen are indebted to middlemen.

Many are also seasonal or part-time fishermen, who engage in agriculture at the appropriate season. They are disinclined to invest in equipment which will stand idle at times. They are among the least educated in society, usually lacking in mechanical skills and often lacking in literacy, perhaps speaking only a tribal language. The fishing effort is usually decentralized, the fishermen living in small remote communities and bound by social and family rules which often make them resistant to change.

STRATEGIES FOR IMPROVING THE STATUS OF FISHERMEN

These circumstances impose severe constraints on organic growth, even given appropriate measures by the state. However, there are appropriate strategies for improving the status of the fishermen, including: introduction of new technology, extension of fishing, and capital assistance; improvements in marketing and communications; improvement in training and education; and provision of infrastructure and institutions.

PRINCIPAL REQUIREMENTS FOR A "LARGE-SCALE" FISHERY

While these measures can help to improve the efficiency of the artisanal fishery, they cannot upgrade it to become a "large-scale" industry. This is apparent when one considers the principal requirements for a "large-scale" industry: large capital inputs, requiring appropriate financial and managerial skills; high-level technology, requiring mechanical sophistication, and frequently other expertise; concentration of the industry in fewer large ports, with consequent investment in facilities; a high level of competence in marketing.

Even if a program to achieve all of these could be mounted for an artisanal fishery, it would clearly have to be on a time scale of generations. Transformation of the artisanal sector to large-scale operations is not, therefore, a practical objective of policy. But the usual objective in a developing country is not the organic transformation of the existing industry but the creation of a modern capital-intensive sector alongside which the older sector may coexist. It implies new methods and technology, and usually new people, both managers and fishermen, with interaction between the old and the new relatively small.

IMPACT OF MODERN INDUSTRY ON OLDER SECTOR

Development of a modern fishery sector usually helps the older sector by expansion of markets, introduction of new processing facilities, better infrastructure, and by speeding up the adoption of new methods and ideas. The modern sector has sometimes provided capital inputs to the old, for example, by providing new boats for catching lobsters or prime fish (financed by processors); or it has enabled inshore fishermen to take advantage of new centralized markets.

These possibilities should be envisaged by fisheries planners, and Government policy should provide programs to develop inshore fishermen's institutions and marketing arrangements, encourage new technology, and assist in relocation and housing.

The resource base of the new sector will usually be different from that supporting the artisanal sector, though it may be exploited by other nations; however, a modern industry has been based on resources partly exploited by the artisanal sector. Introduction in an existing fishery of a higher level technology must have advantages, either in increased catches and lower costs, or in higher prices through better marketing. The impact on the artisanal sector is most strongly felt where the pay-off is only through lower catching costs. If difficulties arise in coping with the resultant artisanal unemployment and distress, the gain in economic welfare may be negative. In the typical conditions of developing countries, with coastal or regional employment problems, any project involving only cost reduction on exploited resources should be viewed with suspicion.

Modern Sector Development

The basis for a modern sector should preferably be landings from resources previously unexploited by the artisanal sector.

Although an adequately elastic traditional market may justify such a development, most new fisheries have been quickly opened up under the impetus of a possibility of exports and new product forms. Instances of these are the Peruvian fishmeal industry and the Central American shrimp fisheries. The physical development problems are much the same, but the nature of the stimulus has important implications for public policy.

Whatever the chosen path to fisheries development, the country's government is deeply involved. Even if reliance is placed on free enterprise, the government is involved through foreign exchange control, nutrition, etc., and much of the infrastructural investment and services must come from public funds. If the government's role is dictated by its political philosophy, it may become involved in full public ownership as well as various incentive measures.

With an appropriate resource, a condition for rapid, self-generating development is adequate profitability. There is plenty of evidence to show that, given this condition, expansion will occur, overcoming all associated problems of training, infrastructure, and innovation.

If dependence is placed on organic growth, considerations of nutrition, employment, regional balance, and foreign exchange are all secondary to profitability. In view of the risks in a new fishery, the high costs of plant and vessel investment, the need for infrastructure and training, and uncertainty as to the long-term dimensions of the resource, the rate of potential return must be high, perhaps of the order of 30–40%. Given this, however, development will almost inevitably take place. Experience suggests that this condition is mostly or only met in relation to export markets.

The reasons are clear. Within an economy there is a tendency toward balance between costs and prices; and low-cost economies usually offer only low prices in their internal markets, so that high rates of profit are only available by selling in high-price export markets. As a first step in a policy of fisheries development, it is therefore essential that the government and fishery planners have a clear conception of the dynamic, or prime mover, of the program.

If the primary objective is creation of an industrial sector which will make an efficient contribution to the gross national product, with high rates of return on investment, the government's policies and measures may be different from those adopted if the development is predicated on considerations of nutrition, employment or foreign exchange. These latter are valid, even overriding, objectives. Cost and profitability considerations do not necessarily give a proper indication of national priorities. However, adequate private, not social, rates of return are necessary to organic self-sustaining growth. This cannot be stressed too much, as it often seems to be assumed that because a project is desirable from a national or government point of view, it ought thereby to be attractive to private investors. Governments, therefore, should be realistic in determining whether prospective returns are adequate to sustain private investment.

If the profitability of the proposed new fisheries sector promises to be adequate, and the prevailing political philosophy permits, reliance may be placed on organic growth, i.e. the process of private investment and decision-making, subject to governmental economic and financial policies. The fisheries policy should then consist of removing constraints on development, providing necessary public investment and services, and facilitating the investment process. If profitability is not so high as to induce spontaneous growth, the government may assist by financial incentives if the industry can become self-sustaining in the foreseeable future. If not, the sector calls for special consideration and treatment.

CONSTRAINTS ON DEVELOPMENT

The principal constraints on development are usually: lack of funds for investment; lack of foreign exchange; lack of technological knowledge and expertise; lack of labor skills; lack of infrastructure.

If the rate of return is competitive with other investment opportunities, capital should be attracted from private sources, but may still be constrained by other factors. Principal among these may be: a relatively unsophisticated capital market, the high element of risk, the amount of capital required for some modern fisheries, and investors lack of familiarity with the special feature and problems of fisheries. Foreign capital may be welcomed but yet inhibited by exchange controls, taxation problems, and political uncertainty. If the sector is only marginally profitable, these factors apply more forcefully, and special incentives may be called for.

The government may seek to expand the capital market in the fisheries sector by institutional methods, such as underwriting a fisheries bank, or sponsoring institutions for insuring fishing vessels. It may also allow special tax provisions, such as accelerated depreciations, favorable to the industry. Such general forms of assistance normally imply little real cost to the economy. They should always be considered in formulating a program for the new sector.

However, when more positive steps are required, consideration will turn to the provision of financial investment incentives in the form of grants and preferential loans. A real cost to the economy and the taxpayer is involved here, and such measures should be employed only when justified by probable future gains. But political and industry pressures may predominate when a decision is to be reached.

With a potential of competitive profitability, the principal argument for investment incentives in the initial phase is rapid growth. Some industries requiring large inputs of infrastructure or a wide range of specialized inputs reach economic efficiency only at a certain minimum size, and assistance to ensure the most rapid attainment of this size is justified. However, care must be taken to avoid undesirable investment, with consequent waste of resources and losses. Assistance of this kind is difficult to terminate for political reasons, even when its object has been achieved, and assistance schemes are complicated to administer. Much depends on local standards of public morality and administrative efficiency. There is a considerable variety in the form which such assistance may take, but they may be classified as capital reducing, cost reducing, and income increasing.

For assisting the initial establishment of a potentially profitable industry, capital reduction is more significant than the others, because the major constraint is the supply of investment funds. If incentives are necessary, attention should be directed to schemes of grants and loans at preferential rates.

Grants Versus Preferential Loans

Capital grants are simplest to administer, being once-and-for-all payments to qualified applicants. But they involve a substantial cost to the economy and, perhaps more important, a substantial outflow from the national treasury. If the needed rate of disbursement of grants cannot be achieved for fiscal reasons, the effectiveness of the program in stimulating rapid initial growth will be impeded, but to spread the grants over a longer period would defeat the object of the incentive. The most effective capital incentive in this case is, therefore, the preferential loan. This makes capital available for fisheries where national capital markets do not respond. Its preferential rate of interest increases the attractiveness of the fisheries sector to outside investors, whose own commitment is thereby lessened, and it may reduce the costs of risk and uncertainty in the new fisheries sector. Many of these objectives may be achieved by other means, such as formation of a government-subsidized and sponsored fisheries bank, but the direct operation of a loans scheme by government gives it a substantial voice in the investment decision, and in implementation of its fisheries policy.

For a given level of state assistance, the impact and effect of a loans scheme on investment can be much greater than that of grants, as the real cost to the state is only on the difference between the preferential interest rate and the market rate on government borrowing, plus administrative costs and bad debts. The loans scheme requires a higher degree of administrative competence and it is effective only when the fishery sector itself is profitable. No artificially low rate of interest will render an unprofitable investment attractive.

Giving such a hidden subsidy may be regarded as unfair and undesirable in view of ultimate profitability, but it is justified by the need to accelerate initial development. For this reason, the use of loans with initial grace periods of low interest, or of deferred interest with ultimate repayment at market rates, may be sufficient incentive.

Such measures, however, should be approached with caution because in the developing countries funds are scarce. They may perhaps be better employed in direct public investment in the fisheries sector, through state companies, partnership agreements, etc., which may be sold off profitably at some future favorable time.

Foreign Exchange Aspects

Much of the initial investment for an industrial fisheries will have a high foreign exchange content. Relatively few developing countries are well placed in this respect.

Where the industry is export-based the problems may be easily overcome by government or private borrowing, or through foreign participation. After the initial phase, future expansion may be paid for out of earnings. Wherever possible, effort should be made to minimize the foreign exchange cost. In many cases it is possible to import the technology and specialized equipment through licensing agreements, without having to import all the major hardware. Unnecessarily sophisticated vessels and plants, designed for a different economic environment, should be avoided as far as consistent with the maintenance of standards and efficiency. Local sources of supply should be used to the fullest extent, and for this reason, as well as the more practical one of ensuring adequate maintenance and servicing, the development plan should include the creation of a shipbuilding and marine engineering industry and the other required service agencies.

If foreign earnings will not be a major part of the revenue, and the development cannot be justified on import-saving grounds, the question can only be resolved in relation to a general economic policy. In countries with rapidly increasing populations and a backward agricultural sector, a sufficiently long forward view will often justify such use of scarce exchange because of rapidly rising costs of food imports.

Some steps may be taken to minimize the foreign exchange costs. If the development is sound, recourse may be had to the World Bank and other international lending institutions for both normal and preferential loans. Bilateral aid is often available from supplier nations as part of their aid programs or through trade credits. As a final and often dangerous recourse there are supplier credits. Experience has shown that such private supplier credits are often disadvantageous in the long run.

Particularly in low exchange earning projects, account must be taken of the continuing need for imports of engines, gear of various kinds, and spares. There have been many instances of new industrial sectors which have been handicapped and even run down to the point of becoming an economic liability through inability to finance the import of necessary spares.

The majority of the new investors and managers will lack specialized knowledge of modern fishing and processing operations, and there will often be a lack of necessary scientific and technological expertise. Few complex operations are simply transported to new environments without difficulties arising from variations in local operating conditions, in fish behavior and quality, in local materials — the list is almost endless. The training of high level technologists and scientists takes too long for much reliance to be placed on this in the initial phase of development, though it should, of course, be pushed hard.

Sources of Assistance

The principal sources of assistance to overcome these various constraints are multilateral and bilateral aid programs, joint ventures, management contracts, training schemes, and building the infrastructure.

MULTILATERAL AND BILATERAL AID PROGRAMS

These have proved to be of great help in opening certain kinds of bottlenecks, particularly in the fields of scientific and technological knowledge. Supporting services of all kinds have been provided by this method, with advice and guidance to counterpart organizations and industry. The cost is relatively low compared with the alternatives, and such programs can mobilize worldwide expertise. Multilateral programs are largely free of the special influences of politics and nationalism.

However, in the free enterprise form of organization, where the great need is for competent decision-takers at vessel and plant level, international or intergovernmental aid programs cannot really be effective, except as general services. For effective operational management in the initial phase, commercially oriented solutions need to be found.

JOINT VENTURES

Perhaps the most common arrangement to provide operational management and solve foreign exchange problems is to form jointly owned enterprises, which may include government participation. This is often the best solution if all partners are fully informed at the outset. Although possible only in a profitable fishery, this fact often appears to be neglected by proposers of joint ventures. In many cases the expatriate partner supplies imported equipment and expertise, often at good prices. This appears to be particularly the case in the sale of second-hand ships and plant. Both the quality and suitability of the equipment, and the prices paid, are often no worse than the developing country could achieve by its own efforts, but the profit made is often seen as the prime motivation of the expatriate partner. Again, many of the large international food and fishing companies are often less interested in a joint venture as an investment opportunity than as a source of supply for their home processing and marketing operations.

Organization of a joint venture is a complex subject, with many variations arising from the above factors, and from others such as exchange controls, repatriation of capital and profits, the problem of majority and minority shareholdings, provision for the training of indigenous staff and management, and so on.

Governments should give early and realistic consideration to the possibility of joint ventures as the most efficient way of providing inputs of capital, technology, management, etc., while indigenous resources are being marshalled and trained.

MANAGEMENT CONTRACTS

If joint enterprises are not feasible, the need for technological and management skills may be met by contracts with foreign consulting or commercial firms, usually involving the payment of fees for specific services. Sometimes governments have been able to secure bilateral or international bank assistance to meet these costs, particularly when the investment is being substantially financed by such sources.

Where joint enterprises may not be feasible, some commercial fishing companies with great experience in fishing operations and management may be willing to provide a full range of technical and mangement services for fees or on a profit-sharing basis. In many countries arrangements are made for vessel management companies to charge a small percentage of the gross landings of the vessels. This also is worthy of consideration where joint ventures are not possible.

Finally, where the output is marketed by large concerns abroad, they may be willing to provide technical services, both in the interest of quality standards and of maintaining their supplies.

TRAINING SCHEMES

In most cases there is a need to train fishermen and plant workers in new techniques. The government can help this demand by orgainizing fishery schools and training schemes, perhaps in cooperation with UNDP/FAO or bilateral programs. Such schemes can greatly accelerate the flow of competent manpower. As many of the required skills are more a matter of manual dexterity than knowledge, on-the-job training is necessary. Even when all other factors are highly favorable, there is a fairly definite maximum rate of growth in the early stages of the new development because of the manpower training requirements. Careful job analysis and the breaking-down of more complicated tasks into simpler jobs may speed up the training process. In such cases there may, indeed, be an initial economic advantage in the employment of labor-saving mechanized processes, despite high local unemployment. In view of this, considerable effort and expense may be justified to shorten the learning period.

INFRASTRUCTURE

In profitable fishing industries, development may have proceeded on the basis of private provision of landing and harbor facilities. Although there can be little objection to this, it frequently gives rise to over-provision and under utilization. However, in most cases, and especially where large sea protection works are necessary, the costs are excessive for a single private firm and the state will usually be required to provide this kind of investment, as well as roads, public services, and most of the other infrastructure, especially that concerned with political and social aspects.

It is, therefore, necessary that the fishery planners have a clear view of the probable future course of a fishery so as to estimate the size and type of facilities required.

This class of project rarely qualifies for private or commercial investment but relies on government funds or, in the longer term, on bilateral or international bank aid.

The costs of the design and appraisal of such projects are usually high, but the UNDP/FAO system is able to assist in this field.

Problem of Overinvestment

Because of the common-property nature of the fisheries resource, profitability may induce a level of investment and fishing effort in excess of that required for the maximum sustained yield. With successful development a point will come when further investment in one or more sectors is to be discouraged. This process is complicated by the activities of other nations in international fisheries. Overinvestment in the various sectors may have multiplier effects on infrastructure and services provided from public sources.

The techniques for controlling this situation have not yet been fully developed anywhere. The logical solution appears to imply a high degree of state control or management, at least in the catching sector. Clearly, the state has a duty to prevent, if possible, harmful overinvestment. The fisheries agency should form a view as to the desirable size of the developing sector, if only to serve as a basis for estimates of infrastructural needs and public services. All incentives to growth should be withdrawn as soon as they become unnecessary — which is, generally speaking, as soon as the investment is self-sustaining.

Where a unilateral management regime is feasible, it should be announced and implemented at an early stage. Such a policy would tend to promote rather than constrain investment by assuring the early investors of a preferential share — often the only incentive needed.

Where the resource is substantially shared with other nations, and no management regime is in prospect, the situation is more complicated, but here, too, care must be taken that the level of investment, prompted by the high initial rates of return, is not unduly excessive in terms of long-run output. Techniques can be developed for assessing the degree of longer-run overcapacity justified by present higher yields and profitability. This is very important in relation to infrastructure investments, such as harbour facilities and fishing terminals.

For a potentially profitable fishery, a combination of the measures outlined, promoting private investment and easing the constraints which usually inhibit development, will usually be sufficient to ensure self-sustaining growth.

If not, and in the absence of special inhibiting factors, careful thought must be given to the national desirability of such a development. If the proposed fishery remains unattractive to private investment, this may indicate a more desirable use of scarce national resources. For this reason, any fishery development proposal should always be viewed within the framework of the overall national economic development plan as well as the fishery sector plan.

The Fishery Within National Development Plans

"Food at all costs" or "the abolition of unemployment" are neither valid economic policy objectives nor operational concepts. Where a proposed fishery development rests on grounds of nutrition or employment, the profitability aspect may be positive but relatively low and unattractive to private investors. Even so, the development may be desirable from a national welfare viewpoint and in the interests of long-term growth.

In these circumstances, it is clearly right for the government to set policy objectives on grounds other than economic considerations only, and fisheries, as a main source of animal protein, must often find their priority set on this basis. However, in such development reliance cannot be placed on private enterprise investment and special measures are needed. Many of the measures previously discussed are applicable in this situation, but the main requirement is substantial and continuing public investment and financial support.

PRIVATE SECTOR

If a private sector exists, or can be created by incentives, the government may adopt a variety of support programs to raise the profitability of the sector to an adequate level. This is, of course, only so justified when there are public welfare benefits of the type outlined earlier, and a great deal of quantitative analysis should be undertaken to assess their existence before embarking on what may be a basically unsound development.

A wide variety of assistance schemes is open to the government and selection will depend on the local conditions.

In addition to the capital incentives already mentioned, recourse may be had to various types of "income-increasing" subsidies, such as payments on the quantity of the catch, or on days spent fishing, or in relation to horsepower, or to labor employed, etc. Other "cost-reducing" methods may be employed, such as subsidized fuel or gear, subsidized harbor and landing dues, etc. The efficiency of these methods varies according to local conditions and the characteristics of the new fisheries sector, and careful study and analysis are required to determine which method is most appropriate.

These measures demand a fairly high level of administrative competence if they are to be efficiently operated, particularly when the fishing sector is located at a distance from the state capital or other main center of administration. In many countries such an administrative task may be beyond their resources and techniques. Where a combination of indirect incentives will not suffice to promote private investment, consideration may be given to direct public investment through an appropriate institutional structure, usually a specially created fisheries corporation.

PUBLIC CORPORATIONS

The public corporation approach has been criticized as being too bound by restrictive civil service procedures or, alternatively, as being too free of political and financial restraint. It is also accused of monopolizing the scarce managerial talent and, at the same time, of being badly managed from a commercial point of view. These are general criticisms levelled against whatever the industry in question may be. With a newly developing fishery sector, particularly in the conditions of poor profitability assumed here, they do need special consideration because of the wide range of problems, involving different technologies and expertise, that have to be overcome. Vessels have to be procured and operated, processing plant installed, scientific research undertaken, harbors and transport facilities established, crews and plant workers trained, and so on. In addition, there is the whole question of domestic and export markets.

A state fishing corporation is the most appropriate institution to undertake this diversity of tasks, to ensure an integrated and coordinated approach. It can, by concentration in one institutional framework, employ what is available to the best advantage, as compared with more diffuse and duplicative private corporation structure.

In most circumstances, it is a more effective method of injecting state assistance into the fisheries sector than the indirect methods discussed above, since the assistance need not be tied to particular aspects of the industry, such as landings or days at sea, etc. In this way the financing of the corporation's deficits from public funds is seen to be an efficient and justifiable method of providing state aid for development of the industry, provided its policies and management are in themselves efficient.

A difficult task is to secure sufficient freedom from civil service controls and procedures to enable the corporation to act quickly and flexibly in what is essentially commercial decision-making. It is frequently preferable to organize the fisheries corporation as a subsidiary to the usually powerful general economic development agency or corporation, rather than as an appendage of the minister responsible for fisheries. The latter should be left responsible for fisheries policy and forward planning. However, no general rule can be made because the decision really depends on the efficiency of public administration in the country concerned.

Finally, a corporation appears to offer the only effective solution, particularly in the conditions of developing countries, to the economic and institutional problems of fisheries resource management based on the control of fishing effort.

Steps in Creating an Industrial Fishery

In the creation of a new industrial sector of the fishing industry, the first step is clearly an appraisal of the possibilities, based on an inventory and assessment of available resources and available technical means. These possibilities can be assessed by existing methods of project appraisal and market analysis, essentially an information-gathering phase. A policy and a plan for its execution then remain to be devised.

The main problem in developing an industrial fisheries sector in the developing countries seems to be the determination of the ratio of private to social benefit promised by the new development. This must be realistically assessed. This will include consideration of nutritional requirements and future population growth, true valuation of foreign exchange and of imports, artificial or institutional restraints on prices, levels of unemployment, and costs of labor, etc.

Inevitably, of course, once the logic of cash flows is abandoned, qualitative and subjective factors will enter into the decision, and it is often felt that the poorly equipped, impoverished, artisanal fishermen are somehow a reflection on the society and should willy-nilly be replaced by modern machinery. This is not the case, and if the proposed modern sector cannot be justified even by the wide range of considerations mentioned above, the government should turn its attention to other sectors of the economy and to alternative sources of food and foreign exchange in the agricultural sector.

Fisheries development should be approached, as is any other industrial project, objectively, and matched against competing projects and investment possibilities. If this is not done well, the resulting industrial sector will not only be a source of loss and a misuse of scarce resources, but will have an adverse effect on the artisanal sector, whose real though perhaps limited potentialities will be destroyed in the process.

Developing Markets for Unfamiliar Species[1]

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The important "unfamiliar" species of fish and other marine animals which it would be desirable to utilize in greater quantities are not so much new resources, which we may be years away from harvesting in significant quantities, but rather those that are available but neglected: these include some species frequently used for the manufacture of fish meal.

In developing countries some progress has been made in utilizing such species more effectively, particularly through the wider use of unfamiliar fish in iced or frozen form, and through the enhancement of low grade species by improved preparation. Much more could be done. In many cases it is not so much the consumer who needs persuasion to be more adventurous in trying new fish and fish products, but industry which should display more initiative in introducing them.

If the problem of introducing unfamiliar fish is to be tackled effectively, industries must become more market-oriented, and in the developing countries fisheries development authorities should strengthen their establishments by adding marketing and processing specialists to engage in more intensive product development and marketing programs. In these countries the most rewarding opportunities lie in improving and increasing the range of existing, acceptable products rather than through the introduction of new products.

Par principales espèces "peu familières" de poissons et autres animaux marins qu'il serait souhaitable d'utiliser en plus grandes quantités, on n'entend pas tant de nouvelles ressources dont peut-être on ne pourra pas tirer grand parti avant des années, que celles dont on dispose déjà, mais qui sont sous-exploitées; il s'agit, entre autres, de certaines des espèces dont on se sert fréquemment pour fabriquer ce la farine de poisson.

Les pays en développement mettent désormais mieux à profit ces espèces, notamment en se servant davantage de poissons peu familiers sous forme congelée ou réfrigérée sous glace, et en rehaussant la valeur des espèces de qualité inférieure grâce à une meilleure préparation. Mais on peut faire beaucoup plus encore. Dans bien des cas, ce n'est pas tant le consommateur qui a besoin d'être encouragé à se montrer plus audacieux dans l'essai de nouveaux poissons ou produits de la pêche, que l'industrie qui doit faire preuve de plus d'initiative pour les lancer sur le marché.

Pour s'attaquer énergiquement au problème que pose l'introduction d'espèces ichtyologiques peu familières, il faut que les industries s'orientent davantage vers les marchés et que, dans les pays en développement, les services officiels responsables d'expansion des pêches se renforcent en s'adjoignant des spécialistes de la commercialisation et de la transformation, afin d'entreprendre des programmes plus intensifs de promotion et de commercialisation des produits. Dans ces pays en effet, on est davantage tenté d'améliorer et d'élargir la gamme des produits existants et acceptés que d'en introduire de nouveaux.

Cuando se habla de especies importantes "no usuales" de peces y otros animales marinos que sería conveniente utilizar en mayores cantidades, no se alude tanto a los recursos nuevos, que tal vez tardemos aún muchos años en explotar en forma sustancial, cuanto a los ya disponibles a los que no se presta suficiente atención, como algunas especies utilizadas frequentemente para la fabricación de harina de pescado.

En los países en desarrollo se han hecho algunos progresos en el aprovechamiento de estas especies, sobre todo difundiendo el empleo de peces no usuales mediante conservación en hielo o congelación o haciendo más atractivas las especies de poca calidad mejorando su preparación. Pero aún podría hacerse mucho más. En muchos casos, lo que hace falta no es tanto persuadir al consumidor a que se aventure a probar pescado y productos pesqueros desconocidos, cuanto lograr que la industria muestre más espíritu de iniciativa para introducir esos productos.

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Si se quiere abordar eficazmente el problema del consumo de especies no usuales, es preciso que las industrias se orienten más hacia el mercado, y que los organismos responsables del sector pesquero en los países en desarrollo completen su plantilla con especialistas en mercadeo y elaboración, que inicien programas más intensivos de preparación y mercadeo de nuevos productos. En estos países, por otro lado, la mejora de la gama de productos ya existentes y aceptables ofrece oportunidades más rentables que la introducción de nuevos productos.

FISHING industries lag behind competitors in other food processing industries in developing markets for their products. This causes lost profit and fluctuating fortunes in the operations of the industries in developed countries. In the developing countries waste and inefficient utilization of fish catches creates a situation inconsistent with policies of supplying food for expanding populations and for developing export markets.

Stimulation of markets is particularly important in developing countries where production is increasing at a fast rate. Guidance is especially needed to make more effective use of this larger production through the development of markets for unfamiliar species of fish.

The phrase "unfamiliar species" cannot be restricted to completely strange species of fish and other animals, but must include species that could be harvested and landed in substantial quantities but are neglected because industry believes that no profitable markets for them exist or can be developed. It must also include fish that are at present discarded, and at least a proportion of those now used for reduction purposes. While fish meal industries make substantial contributions to the economies of the countries that support them, there is some concern about overdependence on fish meal. But such utilization is often based on necessity because reduction offers the only industrial means to process efficiently large fish landings. All too often, however, insufficient attention has been given to alternative and possibly more profitable products and markets, either as partial replacement of the fish meal process or as separate operations.

There are many rejected or wasted fishery resources. One is the so-called trash fish that result from all fishing operations; these are a particularly prominent feature of shrimp trawling. It has been estimated that with every pound of trawled shrimp brought on deck there comes as much as 6–10 lb of various fish, mainly trash, that is usually dumped. On the basis of the lower figure 5 million tons of such fish may be discarded annually. The arguments for dumping are that sorting shrimp is a tedious business that leaves little time for handling low-grade fish, and that the hold space is needed for the more valuable shrimp. These arguments have some validity but they are not wholly convincing. With daily catches of shrimp trawlers ranging from 220 to 270 Kg, many boats do not fill their holds. Could not the surplus space be used for the better quality fish taken, albeit in limited quantities? In many developing countries small fish have a market outlet, particularly in low-earning communities. Some enterprising operators have used such fish for the production of frozen fillet packs, which have found lucrative markets under a variety of names.

Discarded or low-grade species are not a problem exclusive to major unit fisheries, but also feature on a bigger scale than is generally realized in the artisanal fisheries in developing countries. Artisanal fishermen operate on grounds that are usually restricted in area and are already, or will become, overfished. As they become overfished, the catch of recognized top-quality fish — such as demersal snapper and grouper in tropical waters — diminishes while more of the low-grade, low-priced species with limited markets are caught. It has been estimated that the 8 or 9 million artisanal fishermen in the developing countries annually land at least 20 million tons of fish. Studies indicate that as much as 30% of their catch is made up of low-grade species familiar to poorer people, who buy them through necessity. Yet many are good table fish that deserve a wider market. A limiting factor to marketing these fish is often their unusual appearance, such as awkward shape or body structure, which creates prejudice. Some enterprising marketing authorities in developing countries have overcome this by heading, skinning or filleting the fish, and by providing inexpensive but attractive packaging. Such marketing has created increased demand, resulting in a better price to the fishermen. And, since the costs of preparation are relatively small, the price of the product has been kept within the range of lower income groups.

Marketing Possibilities

The fishing industries in developing countries often have more scope and freedom to market low-grade species. In many developed countries food regulations demand that fish products offered for sale be accurately described as to species. In certain cases this in itself is sufficient to kill sales. This can also happen where legislation prohibits even the landing of certain species for use as food fish. Such laws are well-meaning and were usually introduced for the protection of the consumer, but more flexibility in framing and more discretion in applying laws are needed.

One can only speculate as to how much fish used for making fish meal might be diverted into food fish markets. In fisheries like that of Peru it might be a small proportion, but in others it could be significant. In Turkey, for example, production of fish meal from anchoveta is approximately 2000 tons annually and it is planned to increase this to 20,000 tons. Concurrently, it is planned to double the quantity of anchoveta used for food from 40,000 to nearly 80,000 tons, which would allow an increase in present fish consumption by 1 kg per head. The program will require the introduction of iced anchoveta, and the production of frozen blocks which can be delivered to consumer markets in a thawed or semithawed condition and sold as fresh fish. As retail storage facilities are made available, frozen packs will also be introduced. These products will be unfamiliar and they may encounter consumer resistance. Such resistance to iced or frozen fish can be overcome. Often it is not so much that the consumer needs persuading to try something new but that the industry needs to be more enterprising in introducing a new product.

Prejudice against iced or frozen fish is most frequently encountered in tropical countries where it is often regarded as being synonymous with bad fish — frequently with justification. Yet in many of these countries the use of iced or frozen fish is the only way to bridge the gap between supply and demand.

Developing Countries

An example occurred in some Caribbean islands in recent years. The inland populations were traditionally fish eaters, in some cases consuming 40 kg or more per head per year. In many islands, however, fresh fish was in short supply, and heavily dependent on short-lived seasonal runs of pelagic species. Processed fish were imported at a cost exceeding $40 million (US) annually for the region. The solution to the problem was to introduce trawled fish from medium distance fishing grounds. Unfortunately, this fish had two counts against it: it was completely unfamiliar, and it had to be delivered following 11 days iced storage. Those responsible for initiating the development were assured that prospective consumers would reject the fish. The first landings were preceded by a short simple survey to determine suitable selling locations, times, and price ranges. The unfamiliar iced fish was an instant success, sales exceeding all expectations. This enterprise not only ensured adequate fish supplies but had the catalytic effect of bringing about a considerable investment programme in new vessels, and in improved landing and marketing facilities.

Another example of developing markets for unfamiliar fish was in West Africa. A market was created for frozen trawled fish caught by foreign-owned trawlers. Their owners sought local markets for species that had a low value in their home ports. The trade, which now approaches 150,000 tons annually, relies essentially on the landing of 20–30-kg blocks of frozen whole fish. These are transported for considerable distances inland, often in unrefrigerated transport, and are sold in a thawed or semi-thawed condition for use as fresh fish or for processing. It is estimated that this initially unfamiliar fish is contributing as much as 50% of the local fish supplies in certain West African countries. It has provided a means of getting fish to people who otherwise would not have had any. While initial resistance occurred, it was virtually overcome within a few weeks. A study showed that while high cold storage temperatures, lack of refrigerated transport, and poor display methods adversely affected the quality of the product, this quality was far superior to that of the fish formerly eaten. Consumers readily accept it.

In Africa a problem exists on how to create markets for the 200,000 tons or more of a small fish, *Haplochromis*, which may be landed following the establishment of a trawl fishing industry in Lake Victoria. The fish is the least desirable of all the species caught in quantity in Lake Victoria. It is small, bony, difficult to process, and is unfamiliar to people living away from the vicinity of the lake. If it is possible to regulate catching operations to control both volume of landings and the size of the fish, the whole of the catch might be sold in fresh or dried condition. But marketing trials indicate that this is too optimistic a view, and the scale of investment proposed in fleet construction and shore facilities is too great to leave matters to this chance. The development of other markets must, therefore, be planned and energetically pursued. It would not be overstating the case to suggest that this whole fishery development should be market-oriented.

In developing products and sales for *Haplochromis* more attention should be given to expanding the market for fresh or frozen fish. The three countries bordering the lake's shore have a population in excess of 30 million and at least 10 million reside within accessible distance of the proposed landing areas, linked with good communications. Detailed surveys and test marketing can determine the real prospects. Production of fish meal would be a worthwhile subsidiary undertaking, especially as there is a growing market for this commodity in East Africa and in neighboring countries. The scale of the enterprises provides an opportunity for an intensive product development program that could have far-reaching effects in other parts of Africa. In a continent where it is the custom to flavor maize meal, cassava, and plantains with meat and smoked or dried fish, it is surprising that fish has not been used more widely in making sauces, soups, and relishes, such as those of the Far East.

Both in East and West Africa encouraging results have been obtained on a small scale in marketing good quality fish meal for human consumption. In some places it is selling successfully as "Baby Food." Locally made, this meal is fairly finely ground and sieved to remove bones and scales. Above all, it has a strong rich fish flavor, which meets local consumer requirements. The possibility of increasing its production and sale has not been given the attention it deserves. There are opportunities for useful work in this direction in East Africa through collaboration between fisheries and marketing administrations, nutritional workers, and the well-established grain milling firms. Powdered or granulated products of this kind would also help to reduce the present appalling levels of waste and spoilage of dried/salted fish and smoked fish, which occur throughout the continent as a result of insect infestation, bad handling, and bad packaging. In the case of smoked fish, for example, estimated losses run as high as 40%. At the point of sale, after transport over long distances, this fragile, nearly cooked product is often crumbled and broken beyond recognition. This being so, both causes of loss and spoilage — insect infestation and damage — can be removed by producing a powdered or granulated smoked product in the first place. It could be called, say, "Smoked Fish Crumble" and packed in polythene sachets or containers — always a good selling aid in Africa. There is plenty of evidence to indicate that the African housewife appreciates convenience in foods just as much as anyone else, and the powdered products suggested would fit into this category.

Some authorities are concentrating their attention on producing hygienic, high quality, solvent-extracted powdered products for human consumption. It is questionable whether this is the correct approach in Africa. If existing acceptable products can be improved and still retain the taste and flavor the people there like, it is wasteful to incur the expense and trouble of producing a new product that does not please the consumer.

In these case studies from developing areas the most obvious common denominator (except for Lake Victoria) is that a product was not developed for the market but a market was found for some underutilized or unfamiliar fish. In each case the product required no elaborate processing facilities, only simple preparation, like icing or freezing. It is also a fact that the products were often developed and the markets established through the initiative of external agencies or business interests. This highlights a deficiency evident in many developing countries, that fisheries development programmes continue to be production-oriented. One reason is that the fisheries administrations responsible for overall development of the industries are traditionally staffed by biologists and administrators. They are unfamiliar with fish utilization and marketing and are understandably hesitant to engage themselves in it. However, it is not sufficient to leave the responsibility for development to the trade, for although individuals, particularly in Africa, are often enterprising in exploiting profitable opportunities, they usually rely on others to give the lead. It is hoped, therefore, that the worthwhile results arising from the activities described in these cases will encourage fisheries administrations in many developing countries to strengthen their establishments by employing marketing staff. If this is not possible because of limited financial resources, encouragement should be taken from the fact that, in the situations described, as much was achieved through initiative and enterprise as through marketing expertise.

DEVELOPED COUNTRIES

So far, emphasis has been placed on expansion of markets for unfamiliar species of fish in developing countries, since these are responsible for the greater part of the increases in fish production, and they are most in need of additional supplies of food. However, developed countries, whilst not going about it in the same way, could also benefit from product development. Useful experimental work has been done by industries in these countries toward developing products from unfamiliar or underutilized species but it rarely seems to get beyond the pilot stage.

While the quantities of fresh fish sold have remained nearly static over recent years, the quantities used for freezing, canning, and convenience preparations have increased. It is these latter forms of processing that appear to offer considerable scope and promise for increased markets for unfamiliar fish.

While canned meat is usually regarded as inferior to fresh meat, canned fish is often superior to the fresh article. By canning; flavor, color, and taste can be manipulated to meet a wide range of consumer taste, and this offers opportunities for difficult species, like mackerel. The high cost of tin plate and manufacturing equipment makes it difficult to produce a cheap canned fish product, but new materials and processes may help overcome this.

For some species now ignored or used for reduction, such as blue whiting and small cod, the creation of convenience products such as deboned fish flesh is worth considering.

In developed countries no approach to the problem of using unfamiliar fish will be really successful unless the general reputation of fish is improved. In many high-income consumer markets, where the customer is confronted with an ever-increasing range of food, fish is usually a second choice, or a once-a-week meal. Consumers must be taught to accept fish as a prime food before they become adventurous and try unfamiliar species and products. The most widely used selling tag given to fish in many areas is that "it is good for you." As any mother will confirm, nothing is more guaranteed to create instant and long-lasting prejudice. Other food industries facing this problem have enhanced the reputation of their products by intensive campaigns. This is expensive, but it is a price the fishing industries must pay for previous neglect.

Opportunities also exist for processing firms to explore new markets for export commodities. In some developing countries a growing proportion of cured fish imports, previously dominated by dried salted cod, now consists of such species as ling and mackerel. These are cheaper than cod and give the importer a profit despite the price control regulations that are a feature of many developing countries. Both in developing and well established industries the practice of relying entirely on brokers is a handicap. Brokers will always have a role to play, but this should not prevent exporters from making more detailed personal studies of potential export markets to identify additional opportunities.

Not all unfamiliar and neglected fish will find equal acceptance or profitable markets, but opportunities for improving the present situation exist. Supplies of traditionally recognized products such as cod, haddock, plaice, snapper, shrimp, and others are not inexhaustible, and even now some are not available in the quantities required to meet demand. The cost then becomes too high for many consumers. Underutilized species such as mackerel, blue whiting, coalfish, capelin, and some species now used for reduction, should be promoted vigorously.

No mention has been made here of such resources as krill, squid, lanternfish, and others that can perhaps yield another 200 million tons of raw material. However, fishing industries must learn first to market what is already available and to eliminate appalling waste before it can cope with these new and even more unfamiliar resources.

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The Alternative Uses of Fish[1]

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BURGESS, G. H. O. 1973. The alternative uses of fish. J. Fish. Res. Board Can. 30: 2170–2171.

Due to the increasing world deficit in protein supplies, there is an urgent need to make the best use of every possible protein source. Fish is widely recognized as an excellent source of protein of a very high quality. At present more than one third of the world fish production is converted to fish meal and fed to pigs and poultry. As the total world catch has increased so has the percentage converted to fish meal tended to increase. There are many other ways of utilizing fishery resources directly for human consumption and this paper indicates possible means of achieving this. After considering the supply of fish and its utilization, the chief requirements for the establishment of a fishery are identified. Such factors as the type of raw material available, the structure of the catching industry on one hand, and the system of distribution and sale on the other, the availability of processing equipment and skill, etc., are all considered for various situations.

The problem of the acceptability of new fish products in developing areas cannot be overemphasized. Consumer preference studies are required to identify more closely the types of products which are likely to be accepted. The choice of products is reviewed systematically considering traditional methods of processing as well as special methods including certain experimental ones, e.g. irradiation, freeze-drying, and the manufacture of fish protein concentrate.

It is concluded that so far as modern products need to be developed, greater success will probably be forthcoming for those based on the traditional methods of preservation used in the area in question. It is felt there is scope for the application of modern food technology in this area.

Etant donné le déficit mondial croissant en disponibilités protéiques, il faut, de toute urgence, tirer le meilleur parti de toutes les sources possibles de protéines. Le poisson, comme on s'accorde à le reconnaître très généralement, en est une excellente et de très haute qualité. A l'heure actuelle, plus d'un tiers de la production mondiale de poisson est transformé en farine pour l'alimentation des porces et de la volaille. A mesure qu'augmente le total des prises mondiales, la proportion de poisson transformé en farine tend elle aussi à s'accroître. Il existe de nombreaux autres moyens d'utiliser directement les ressources halieutiques pour la consommation humaine, et l'auteur en indique quelques-uns. Après examen des disponibilités de poissons et de leur utilisation, il définit les principales exigences auxquelles doit satisfaire la mise sur pied d'une pêcherie. L'auteur examine aussi divers facteurs comme d'une part, le type de matière première disponible et la structure de l'industrie de la pêche, et, d'autre part, du système de distribution et de vente, les disponibilités en équipement de transformation et en personnel compétent, etc.

On ne saurait trop souligner l'importance que revêt le problème de l'acceptabilité de nouveaux produits de la pêche dans les zones en développement. Des études sur les préférences des consommateurs sont nécessaires pour déterminer avec plus de précision les types de produits susceptibles d'être acceptés. Le choix des produits est réexaminé systématiquement en fonction à la fois des méthodes traditionnelles de transformation et des méthodes spéciales, dont certaines expérimentales, comme l'irradiation, la lyophilisation et la fabrication de concentrés de protéines de poisson.

Dans la mesure où il est nécessaire de mettre au point des produits modernes, l'auteur conclut que ce sont ceux qui font appel aux méthodes traditionnelles de conservation utilisées dans la zone en question qui rencontreront le plus de succès. Cette région se prête, estime-t-il, à l'application de techniques alimentaires modernes.

El continuo aumento del déficit mundial de proteínas hace urgentemente necesario aprovechar al máximo todas las fuentes de proteínas disponibles. Es bien sabido que el pescado constituye una fuente excelente de proteínas de altísima calidad. En la actualidad, más de un tercio de la producción mundial de pescado se transforma en harina y se utiliza para alimentar cerdos y aves de corral. Al aumentar las capturas totales mundiales, ha aumentado también el porcentaje transformado en harina. Existen otras muchas maneras de aprovechar los recursos pesqueros directamente para el consumo humano, y en el presente trabajo se indican varias posibilidades. Tras examinar el suministro de pescado y su aprovechamiento, se identifican los prin-

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

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cipales requisitos para la mejora de una pesquería, estudiando en situaciones diversas, factores tales como la disponibilidad de materias primas, la estructura de la industria pesquera, el sistema de distribución y ventas, la disponibilidad de equipo de elaboración y personal especializado, etc.

Nunca se insistirá demasiado en el problema que plantea la aceptación de neuvos productos pesqueros en las zonas en desarrollo. Es preciso estudiar las preferencias de los consumidores para determinar con mayor exactitud qué tipo de productos pueden encontrar aceptación. El autor examina sistemáticamente la elección de productos, reseñando tanto los métodos tradicionales de elaboración como algunos métodos especiales, e incluso experimentales, como irradiación, liofilización y fabricación de concentrados de proteínas de pescado.

Se concluye que, como es necesario preparar productos modernos, probablemente encontrarán mayor éxito los basados en los métodos tradicionales de conservación de la zona en cuestión. Existen buenas posibilidades de aplicar en este sector la tecnología alimentaria moderna.

The text of this contribution to the Conference was issued in 1971 as FAO Fishery Report No. 177, and is not repeated here.

Experience and Plans for Rationalization of Small-Scale Fisheries in India[1]

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GEORGE, P. C. 1973. Experience and plans for rationalization of small-scale fisheries in India. J. Fish. Res. Board Can. 30: 2172–2177.

Small-scale fisheries have traditionally been the backbone of the fishing industry all over the world. Although large-scale mechanized fishing has come into the limelight recently, even such countries as have developed substantial capability in this direction still have a large fleet of small boats in coastal areas. The landings of this sector of the industry are always substantial, and in many countries they still dominate the picture. In India, small-scale fisheries landed almost 1.15 million tons in 1971. This figure has been increasing as motor-powered small craft have increased in numbers, although 70% of marine fish is still caught from nonpowered boats. Measures taken to increase fishing capacity, landings, and net fishermen's income over the past 10 years include various kinds of loans and subsidies for the purchase of boats, motors, and nets; assistance for the construction of ponds in inland areas; organization of cooperatives; training programs for fishermen and supporting personnel, especially motor repairmen (with the cooperation of Norway); and gear and vessel research including pilot-scale demonstrations with new types of vessels and equipment.

Traditionnellement, dans le monde entier, les activités halieutiques reposent sur la petite pêche. Bien que la grande pêche industrielle tienne depuis peu la vedette, même les pays qui ont développé un potentiel considérable dans ce sens possèdent encore une vaste flottille de bateaux de petites dimensions dans les régions côtières. Les quantités débarquées par ce secteur sont toujours importantes et, dans de nombreux pays, continuent à l'emporter sur les autres. En Inde, les mises à terre des petites pêcheries se sont montées à presque 1,15 million de tonnes en 1971 et ce chiffre continue à augmenter au fur et à mesure que le nombre de petites embarcations motorisées s'accroît, bien que les bateaux dépourvus de moteurs continuent à assurer 70% des captures de poisson de mer. Les mesures prises au cours des 10 dernières années pour développer la capacité de pêche, débarquer des quantités plus importantes et augmenter le revenu net des pêcheurs comportent, entre autres: divers types de prêts et de subventions pour l'achat de bateaux, de moteurs et de filets; la fourniture d'une assistance pour la construction d'étangs à l'intérieur des terres; l'organisation de coopératives; la mise au point (avec la coopération de la Norvège) de programmes de formation destinés aux pêcheurs et au personnel auxiliaire, notamment les mécaniciens chargés de séparer les moteurs, enfin, des recherches sur les engins et les navires, y compris des démonstrations à échelle pilote avec de nouveaux types d'embarcations et d'équipement.

Las pesquerías en pequeña escala han sido tradicionalmente la espina dorsal de la industria pesquera en todo el mundo. Aunque recientemente ha aparecido en escena la pesca mecanizada en gran escala, incluso aquellos países que han obtenido una experiencia valiosa al respecto todavía cuentan con grandes flotas de pequeñas embarcaciones en las zonas costeras. Las descargas de este sector de la industria son siempre importantes y en muchos países aún son preponderantes. En la India, las pesquerías de pequeña escala desembarcaron casi 1,15 millones de toneladas en 1971. Esta cifra ha ido en aumento al ser mayor la cantidad de pequeñas embarcaciones motorizadas, aunque un 70% de la pesca marina todavía se efectua con embarcaciones sin motor. Las medidas tomadas para aumentar la capacidad de pesca, descargas e ingresos netos de los pescadores en los últimos 10 años incluyen diversas clases de préstamos y subsidios para la compra de embarcaciones, motores y redes; asistencia para la construcción de estanques en zonas continentales; organización de cooperatives; programas de capacitación para pescadores y personal auxiliar, especialmente motoristas (con la cooperación de Noruega) e investigaciones sobre equipo y embarcaciones además de demostraciones de nuevos tipos de barcos y equipo.

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

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ALTHOUGH a majority of countries either participate in or are planning to participate in highly mechanized fishing, sometimes in distant waters, they commonly also have small-scale operations that have been the traditional backbone of their fishing industry. In India, for example, there are nearly 100,000 nonpowered coastal fishing craft, mostly plank-built boats and dugout canoes. There are also 10,700 small mechanized coastal boats in the range 5–25 tons and 10–60 hp, most of them 10-12 m long. In 1971, out of a total marine production of 1.16 million metric tons, the nonpowered boats landed nearly 70% of the catch, while the 10,700 mechanized boats and 58 large vessels contributed the remaining 30%.

Even in countries with a large capacity for mechanized fishing, the small-scale coastal industry is far from insignificant. In Japan, for example, it has been estimated that nearly 200,000 nonpowered boats operated in marine waters in 1965. There were also nearly 200,000 motor boats of less than 5 tons, and 15,500 between 5 and 19 tons.[2] The nonpowered boats accounted for nearly 15% of the Japanese catch in 1968. In Norway also nearly 30,000 boats, mostly about 10 m long, were estimated to be in operation in 1965, in addition to a large number of small decked boats. This suggests that small-scale fisheries will not and should not disappear. Rather we should work to make them a viable component of an overall fishery policy. Furthermore, small coastal craft typically bring in greater returns per unit of investment, both in terms of money and in terms of quantity of fish landed — an important consideration in countries where capital is scarce. This paper outlines India's experience since 1955.

Present Status of Small-Scale Fisheries in India

The importance of small-scale fishing in a typical developing country like India is illustrated by the following figures on nonpowered and coastal mechanized boats in operation in India, and their catch:

	Indigenous boats (approximate)	Mechanized boats	Total catch (metric tons)
1955	100,000	863	596,000
1960	100,000	2,161	800,000
1965	100,000	5,206	824,000
1966	100,000	6,006	890,000
1967	100,000	6,953	863,000
1968	100,000	7,698	904,000
1969	100,000	8,722	912,000
1970	100,000	9,743	1,075,000
1971	100,000	10,698	1,155,000

While the number of nonpowered boats has been more or less constant, the number of coastal mechanized boats in operation has risen steadily, reaching 10,698 in 1971. During this period of 15 years these boats have doubled their catch, from 0.6 to 1.2 million metric tons. It is envisaged that mechanized boats will continue to increase at a rate of about 1000 a year during the next decade. Thus it is evident that small-scale fisheries and their management will increase in importance.

Objectives of Development

The objectives of small-scale fishery operations are twofold. On the one hand they provide direct and indirect employment to a large number of people, including those engaged in fishing, boat construction, gear production, processing, and marketing. Simultaneously small-scale operations are substantially increasing fish production, which is the cheapest source of animal protein in India, and this can be made available in increasing quantities to a wider sector of the population. A secondary set of objectives relates to the distribution of the benefits from coastal fishery development, which should aim at a better deal to the producer and consumer and a reduction of the benefits that accrue to intermediaries.

Providing gainful employment to a large number of people has been accepted as a main objective of development activities like the present one. In many maritime countries the coastal districts are heavily populated, although the land there is less productive than in the interior. Soil salinity and effects of sea erosion render many coastal lands unsuitable for intensive agriculture and livestock development. Hence people in coastal villages look to the sea for much of their livelihood.

Problems and Bottlenecks

The problems facing the small-scale operator are centered around the economics of acquisition and operation of fishing craft and gear, and the establishment of sound marketing arrangements whereby he gets a firm and reasonable price for his catches. Uncertainty of the catch is a major obstacle. Either too few fish on certain days or unusually heavy catches on other days create problems for the small entrepreneur. The bottlenecks in this sector, as in any weak sector of the economy, are lack of adequate financing and managerial expertise at various levels to ensure steady operation and reasonable return. Small-scale fishermen are frequently heavily in debt for their boats and nets and even for off-season maintenance of the operator and his family. Typically these loans come from a fish-buyer, and the fisherman is then obliged to sell his catches at prices arbitrarily fixed by the man to whom he is indebted. The influence of such middlemen is strong in a number of countries; they exploit the uncertainties of fishing to the disadvantage of the small operator who cannot accumulate sufficient reserves to break out of the circle, nor obtain facilities to store his excess catches. Few operators have skill in marketing as well as in fishing. The small operator thus requires assistance to improve his equipment, his efficiency, and his economic situation generally.

During its third and fourth 5-year plans, India embarked on a large-scale program of assistance to small operators engaged in inland and marine fishing. The assistance is either provided directly by the Central Government or is channelled through State Governments. In the inland fishery development programs, where natural ponds are not extensive or where existing ponds and tanks are silted up, the Government is providing assistance both by way of loans and subsidies for construction of ponds and for the reclamation of existing ponds and tanks. The scale of assistance varies from state to state, but as a rule the subsidies are higher in the relatively backward areas where construction costs are greater. In addition all states provide fry for stocking at a subsidized rate.

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[2] FAO Bulletin of Fishery Statistics, No. 14, Fishing Fleet Statistics, 1966.

The most important program for development in the marine sector in India is mechanization of fishing vessels. A wooden hull about 10 m long costs Rs 20,000–30,000, and an engine costs nearly Rs 50,000. Thus the money needed to own a power boat is far beyond the means of an average fisherman, so the cost is covered by Government loans, or by loans granted by the Agricultural Refinance Corporation or Commercial Banks. In the initial years of planning, a good part of this amount was covered by Governmental subsidy. The subsidy allocation has been progressively reduced, and now fishermen are encouraged to form cooperatives that can obtain financing from credit institutions. However, subsidies are still being continued, mainly for purchase of engines.

Fishermen's cooperatives receive support from State Governments in the form of a managerial subsidy, share-capital contributions, and subsidies and loans for construction of warehouses, ice plants, and trucks; also contributions toward the cost of boats and engines. Financial assistance for purchasing fishing twine and nets, rope, winches, and other fittings is also provided. The pattern of assistance varies greatly from state to state.

Operational costs are also subsidized, particularly in the matter of fuel costs. Diesel oil in India is subject to a high excise duty and a sales tax. This fiscal policy is based on the economics of the operation of heavy diesel trucks, where the margin of profit is sufficient to bear the burden. In the fishing industry a partial rebate of the excise duty has been allowed for larger vessels and proposals are under way to extend this concession to the coastal fishing boats also.

Governmental assistance also extends to socioeconomic development of the fishing community. In some states a house site and a small house are given free of cost, whereas in other states assistance is limited to a certain percentage of the cost, or as a recurring payment for maintenance. Approach roads from coastal fishing villages to the nearest railhead or national highway have been constructed, potable water and electricity have been brought to villages, and simple processing facilities like curing sheds and ice-plants are being provided at several centers in many states.

Strategy for Development of Small-Scale Fisheries

The general strategy adopted for the development of coastal fisheries, through the operation of nonpowered as well as powered boats, is mainly to generate self-reliance and self-help among the small entrepreneurs, by rendering assistance in the procurement and replacement of boats and gear, through fishermen's cooperatives as far as possible. In viable areas that already have a sound cooperative structure the strategy is to promote integrated coastal fisheries development schemes involving the operation of mechanized boats. An attempt is made to integrate a whole spectrum of activities, including training of fishermen, introduction of mechanized boats, improved fishing operations, and better processing and marketing. Research schemes are undertaken that have direct application to the development of small-scale fisheries, reducing costs and increasing efficiency of operation. Another aspect is to introduce comprehensive fishery legislation to safeguard and protect the interests of small-scale operators.

INCREASED USE OF BETTER CRAFT AND GEAR

Fishermen as a community are conservative and tend to rely on their traditional types of craft and gear. It is true that the boats and gear in use in some regions, although primitive in design, are quite efficient and may be the ones best suited to the particular area. In other places, however, innovations can greatly improve the level of catch. And larger catches have become necessary in several areas due to increased competition and a lower margin of profit. Scarcity of the right type of wood at reasonable prices and of skilled labor to build boats has increased the cost, so that in several areas traditional types are now prohibitively expensive. It has become necessary to use alternative materials such as ferrocement,, fiberglass or aluminum, or to treat traditional wooden craft with an efficient preservative to raise their span of life. The approach should be that fishing vessels should be within the reach of small-scale investment and should not require large recurring bills for repairs and maintenance. The rapid growth of coastal fishing depends to a great extent on the quick development of prototypes of small fishing boats with nonconventional materials, and on extension work to obtain ready acceptance of such boats by the fishermen.

Absence of adequate and reliable statistics on catch, effort, and prices has become a handicap to the planned development of coastal fisheries. The innumerable landing centers and the absence of any fixed schedules of arrival and departure of boats have made the collection of statistics from small boats extremely difficult. Unlike bigger vessels, the small boats do not generally keep any data on kinds and amounts of fish caught or their area of operation. The problem of collecting and compiling reliable statistics from nonpowered vessels is still more complicated because a good part of the activity is in the form of subsistence fishing. Although the quantity of fish they take is quite appreciable, it does not enter into the official statistics.

As already indicated, about 100,000 traditional fishing craft operate along both coasts of India, and account for nearly 70% of the total catch of sea fish. However, there has been a phenomenal increase in small motor vessels engaged in coastal fishing, from 863 in 1955 to 10,698 in 1971. These include traditional boats that have been motorized as well as new types. The labor employed in this sector is 1.2 million. The combined activity of traditional and mechanized vessels now produces 1.15 million tons of marine fish, of which only 3% is landed from large vessels.

FISHERY EDUCATION AND TRAINING

One of the main drawbacks in coastal fishing operations is the lack of the skills needed to operate and maintain small motor vessels, and to construct and repair fishing gear. Modern techniques of fish handling, at sea and ashore, also require trained personnel. One way of ensuring a steady and reasonable margin of profit to the small operator is to see that his boat is in operation for the maximum possible number of days. Maintenance and repair of engines and fishing installations, and easy access to the purchase and installation of spare parts, are very important in improving the economics of his operations. Servicing centers have to be opened for the benefit of the small-scale operations so that their boats will be tied up for the minimum period.

Fishermen Training Centers have been established in most of the maritime states of India. These train young men, particularly from sea-faring communities, in the operation and maintenance of boats, in navigation, and in handling different types of gear.

The duration of courses conducted at the various Centers varies from 6 to 12 months. In all, 23 such Centers have been established, in eight different states. They can train about 900 students at any one time, the courses varying from 4 to 12 months in length, usually 9 or 10. Such a training capacity appears sufficient to meet the present requirements of trained personnel for operating smaller fishing vessels in India.

It is also necessary to provide training in handling the catch on shore and to develop skill in fish processing and in other ancillary activities. The Indo-Norwegian Project conducts such training courses for small fishery operators and fish processors. Up to 1971 95 persons had been given 6- or 12-month courses in one of five specialities: freezing plant operation; processing techniques; design of fishing boats; service mechanics; and purse seining.

Utilization of Inexpensive Varieties of Coastal Fishes

The problem of small trawlers all over the world has been the low price that is obtained for a major part of their catches, which are often classified as "trash fish." Often the percentage of quality fish fluctuates widely, and this brings down the value of the total catch. It is necessary to ensure that "trash fish" are suitably marketed so that a fair price is obtained by the producer. In India pilot experiments have been conducted to process "trash fish" into simple acceptable products like fish fillets, fish sausages, and other items. Frozen and nicely packed products from "trash fish" are now finding a ready market, particularly in the interior, so this bold experiment has great promise.

Converting inexpensive varieties of fish into fish meal is often suggested as a method for the quick utilization of trash fish. This requires serious consideration in view of the fact that the first concern of coastal fishery development should be to fill the protein gap of the people of the area. Conversion of these varieties into acceptable edible products should have priority over their reduction to meal for purposes other than direct human use.

Fish Marketing

Marketing the catches brought in by coastal fisheries has been one of the major problems for the planners in coastal fishery management. Unless markets are planned to absorb all his catch, the producer cannot be assured of a reasonable return. The fishermen themselves have tried to solve the problem by handing over catches to their womenfolk to sell in the market, or to middlemen who purchase large catches for bulk sale in the interior. Both these measures, however, are disastrous for the small operator. For this reason the Government has been encouraging fishermen to organize marketing cooperatives.

Fishing for Export

Although the objective of small-scale fishing is mainly to provide employment and increase local consumption, the export earnings from small-craft landings are quite sizable. Table 1 illustrates the fact that once suitable resources are located, the export earnings from small-scale fisheries can be highly significant.

Cost and Earnings of a Coastal Fishing Vessel

About 11,000 small-scale mechanized boats have completely revolutionized the export pattern of marine products in India(Table 1). With increased insight into the problems of export trade, the producer has reached a stage where his product commands a price commensurate with what the product fetches in the export market. The landed value of exportable varieties of fish, prawns and shrimps in the 1950s averaged only Rs 1.25/kg. The present price has risen to Rs 11.50 for the same; and although there has been some increase in operational and labor expenses, the earnings of the small-scale operator have greatly increased (Tables 2 and 3).

Table 1. Exports of marine products — foreign exchange earnings. (Q: Quantity in metric tons; V: Value in millions of rupees).

Items	1969-70		1970-71		1971-72	
	Q	V	Q	V	Q	V
Frozen prawns	21,150	259	22,135	245	24,592	371
Canned prawns	1,648	23	2,510	39	1,581	25
Frozen frog-legs	1,096	16	2,447	30	1,367	13
Frozen lobster-tails	556	10	266	5	347	14
Dried fish	5,522	14	6,557	17	6,278	14
Total (including other items)	31,695	335	35,883	351	35,523	446

TABLE 2. Operational costs of mechanized and traditional boats in 1968–69.

State	Mechanized boats					Traditional boats			
	Avg. operational cost (*Rs*)	Avg. expenditure on (in Rs)				Avg. operational cost (*Rs*)	Percentage on		
		Repairs & replacements	Fuel & lubricants	Salary & wages	Others		Repairs & replacements	Salary & wages	Others
Andhra Pradesh	27,133	6,531	10,500	9,120	982	10,204	14.5	85.5	–
Gujarat	5,535	735	1,694	2,955	151	1,204	16.0	81.3	2.7
Kerala	14,740	3,276	6,910	3,581	973	3,124	10.1	89.9	–
Maharashtra	20,781	2,203	6,309	9,531	2,738	4,970	8.4	69.0	22.6
Mysore	13,689	4,140	5,095	2,757	1,697	591	100.0	–	–
Orissa	11,603	1,630	3,551	5,111	1,311	202	37.9	–	62.1
Tamil Nadu	32,950	6,022	12,677	11,844	2,408	7,547	22.6	66.4	11.0
West Bengal	6,874	596	130	6,009	139	15,348	4.7	94.0	1.3
All India	17,684	3,216	6,355	6,549	1,546	4,608	14.7	76.9	8.4

TABLE 3. Gross returns (weight and value) per boat and per day in the sea for mechanized and traditional boats during 1968–69.

State	Mechanized boats				Traditional boats			
	Gross return per boat per annum		Gross return per day		Gross return per boat per annum		Gross return per day	
	Weight (*kg*)	Value (*Rs*)	Weight (*kg*)	Value (*Rs*)	Weight (*kg*)	Value (*Rs*)	Weight (*kg*)	Value (*Rs*)
Andhra Pradesh	36,940	33,531	187	170	15,530	13,940	67	60
Gujarat	13,390	12,838	67	64	5,050	4,834	28	27
Kerala	19,570	21,825	132	147	11,380	4,241	62	23
Maharashtra	21,930	35,054	122	194	6,250	8,300	37	49
Mysore	30,821	23,669	206	159	59,429	12,583	404	86
Orissa	26,140	19,639	228	172	1,670	1,115	11	14
Tamil Nadu	76,540	39,291	408	209	29,310	9,769	117	39
West Bengal	1,496	2,396	24	38	7,750	28,865	82	304
All India	29,366	26,899	171	157	17,675	8,931	99	50

INCREASED EMPLOYMENT VERSUS IMPACT OF MECHANIZATION

In considering increased returns to the small-scale fishery operator through more efficient operation and gradual reduction of operational costs, it has always been a problem to decide on the desirable level of mechanization in relation to the optimum number of people that should be employed.

In a recent report by Professor Gerhardsen the impact of mechanization of small fishing craft on the economy has been brought out. When fishing activity is reorganized along modern lines the number of people employed on a small boat is appreciably reduced. Motorization of the craft saves several of the hands formerly needed to row the boat to the fishing grounds and back. Mechanization of the fishing operation itself, particularly the use of mechanical devices, reduces the number of people needed for this purpose. Hence a perennial problem in fishery management is how we should arrive at the optimum level of utilization of manpower resources. Engaging more people in shore activities, extending areas of operation into deeper waters, and intensification of fishing activity in other areas are natural remedies for the situation, as far as they go. In the development of small-scale fisheries the most important factor is the human one, particularly from the angle of unemployment and underemployment. In a recent study conducted in the Laccadive Islands of the

Indian Union it was found that the traditional pole-and-line boat employing 13 persons can fish effectively with a reduced crew of nine once the vessels are motorized. While this is true in this particular case, in several others mechanization has meant only an easier approach to the fishing grounds and return at the operator's convenience, irrespective of the vagaries of wind and weather.

SHORE FACILITIES FOR COASTAL FISHERY DEVELOPMENT

While at the major fishing harbors full facilities are indispensable for big fishing vessels, for coastal craft simple landing and berthing facilities are sufficient but are very important. A simple landing jetty, a maintenance and workshop center, facilities for taking on oil and water at the berth are needed everywhere at places where small operators congregate, and ice-plant, cold storage and even frozen storage facilities are extremely useful.

FUNDS AND FINANCE

In general, coastal fishermen lack funds and a suitable source of credit. The "middleman" has become a source of credit in many places and to replace his dubious financial services with something better is an uphill task. The coastal fishermen generally want funds in a hurry. Even the simple but often lengthy procedures that cannot be dispensed with in ordinary administration act as a strong deterrent to their use by the fishing community; rather than brook delay they rush to the money-lenders. The fisherman has no asset to offer except his skill in fishing, which has not so far been accepted by any financing agency as adequate security. The middleman, however, has always been ready to offer financial assistance to meet not only operational requirements but also social needs, and the rate of interest never bothers the fishermen as much as the readiness with which he can obtain the funds. This has been a chronic problem in all the developing countries. A sympathetic approach and liberal terms with normal guarantees, alone can replace the middleman in this role. In this area the performance of cooperatives has never been a complete success. The main reasons for this may be that the cooperative societies themselves are often financially and organizationally weak in their primary task of providing shore facilities and marketing services. With Governmental backing this situation should gradually improve, and financial assistance for construction of boats and purchase of engines, which hitherto has been granted to the fishermen directly, is now being channelled through cooperative societies. Strengthening the cooperative institutions with 50% participation of cooperative banks, and also compulsory marketing of fish through these societies, has been adopted as policy in some states.

COASTAL FISHERIES PROJECTS IN THE COOPERATIVE SECTOR

One development of considerable significance is the entry of the Agricultural Refinance Corporation of India into financing integrated coastal fisheries projects concerned with the operation of mechanized boats. Up to June 30, 1972 the Corporation had approved 11 coastal fisheries projects in the cooperative sector in the States of Andhra Pradesh, Kerala, Maharashtra, Mysore, Tamil Nadu, and Pondicherry, involving 729 mechanized boats. The outlay for all the schemes is of the order of Rs 63 million, including Rs 45 million from the Agricultural Refinance Corporation. The balance is financed by the State Governments concerned. Under these integrated projects certain members of the fishermen's cooperatives in question are trained at the State's Fishermen Training Centers and are provided with mechanized boats with the financial assistance given by the Corporation. The Cooperative concerned organizes supplies and services to the fishermen, including facilities for marketing. From the proceeds of sales, deductions are made by the Cooperative toward repayments to the Corporation. In addition to the operation of mechanized boats undertaken by its members directly, the Cooperative is assisted financially by the Corporation in setting up boat-building yards, oil pumps, servicing centers, processing plants, and retail stalls for the sale of fish. So far 240 powered boats have been successfully introduced under this program.

COASTAL FISHERY RESEARCH PROGRAMS

To streamline management techniques for small fishery operators it is necessary to carry out continuous research on the resources of the seas, on boats and gear, and also on handling, storage, marketing, and distribution. Increased labor costs and operational expenses by way of fuel, etc., exert continuous pressure on the economic returns of the fishermen. Construction of traditional fishing craft has become expensive due to scarcity of raw materials. Alternative materials have to be sought, and boats made of aluminium, fiberglass, and ferrocement must be tested for their performance and long-term profitability. Research scientists have to identify a type of material which will not only reduce capital costs but also eliminate heavy maintenance charges. Optimum power for the engine has to be determined with special reference to the type of fishing activity, so that fuel can be conserved. Simple storage and processing facilities on board ship, and better handling of fish on board and ashore, demand study in order to bring to the consumer a more wholesome product which in turn means a better return to the producer. Sophisticated processing techniques and quality control are necessary in export products, but simple cured products are readily accepted within the country. In many developing countries the need is primarily to increase ordinary curing facilities and market such products in the interior. This will go a long way toward solving the marketing bottleneck for small operators. Research is needed on processing "trash fish' to forms acceptable for human consumption, and market research is desirable to locate additional areas where the products can be sold at economic prices.

Another area in which research could be profitably focused is investigations on the possibilities of carrying out different fishing operations from the same boat. For example, trawling has been practised to the point of uneconomic return in several areas, although pelagic fish are abundantly available in the superjacent waters. If the small operator can have an "all-purpose" boat suitable both for trawling and gillnetting, or any other type of activity, he can improve his earning capacity. This should receive greater attention in view of the low profitability reported in several areas where a single type of fishing activity has been greatly increased.

Marine Aquaculture: Problems and Prospects[1]

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Aquaculture is the technique of raising useful aquatic species under some control of the organism and its environment. It is expected to supplement fishing by adding significantly to supplies of protein food, but it is unlikely that it will ever replace fishing as the principal means of exploiting the sea.

Discussions are often confused because there are a number of distinctly different procedures embraced by the term aquaculture, with different chances of development into major industries. One type involves raising fish and other animals in hatcheries for release in the sea with the expectation of increasing commercial catches. For most of the very large number of mature animals cultured in this way proof is lacking that any benefits have accrued. Capture and confinement of young is a second kind of aquaculture. This can involve various degrees of supplemental feeding. A third kind involves production of young from eggs obtained from wild parents. The last kind of aquaculture, and the one that is equivalent to land farming, involves hatching of young from eggs obtained from brood stock maintained by the farmer. Not many examples of the last two types exist yet.

The areas at the edge of the sea suitable for aquaculture are very large; e.g. perhaps at least 1.5 million ha in Asia and perhaps half a million ha in Nigeria alone among African countries. Potential production depends on many imponderables, but is believed to be very large — perhaps 10 times present production.

Aquaculture has developed with very little help from scientists, and the solution of technical and engineering problems would advance its rate of development greatly. The kinds of problems that should be solved include: the search for species suitable for culture; research on nutrition of cultured animals and development of suitable food; pathology of cultured animals; studies on the behavior of cultured animals; engineering studies; studies of pollution and the use of waste substances and heat; legal research; economic and social research.

It is proposed that a small number of regional centers for aquaculture be established to study the most pressing problems.

L'aquiculture est la technique qui permet d'élever des espèces aquatiques utiles en soumettant les organismes et le milieu à un certain contrôle. On espère que l'aquiculture complètera la pêche en accroissant substantiellement les approvisionnements d'aliments protéiques, mais il est peu vraisemblable qu'elle se substitue jamais à l'activité halieutique comme principal moyen d'exploiter les mers.

Le terme aquiculture donne parfois lieu à une certaine confusion, car il recouvre un certain nombre de procédés nettement différents qui offrent des possibilités variés sur le plan du développement industriel. L'un de ces procédés suppose que l'on élève des poissons et autres animaux aquatiques dans des centres de reproduction pour les lâcher ensuite en mer dans l'espoir d'accroître les captures commerciales. Pour la plupart des animaux matures ainsi élevés, l'on n'a pas de preuve que cette activité ait donné des résultats profitables. Le second procédé est constitué par la capture et le confinement d'alevins. Ceci peut être accompagné à divers degrés d'une alimentation supplémentaire. Un troisième type d'activité prévoit la production de juvéniles à partir d'oeufs issus de géniteurs sauvages. Dans le dernier type d'aquiculture, celui qui équivaut à l'élevage terrestre, l'alevinage est effectué à partir d'oeufs provenant d'un stock géniteur entretenu par l'exploitant. Il n'existe encore que peu d'exemples des deux derniers types.

On trouve en bordure des mers de vastes zones qui conviennent à l'aquiculture; par exemple, ces zones représentent au moins 1,500,000 ha en Asie, et peut-être un demi million d'hectares dans le seul Nigeria, parmi les pays africains. Leur production potentielle dépend de nombreux impondérables, mais elle passe pour considérable — peut-être dix fois la production actuelle.

L'aquiculture s'est développée sans guère être aidée par les chercheurs, et en apportant une solution aux problèmes techniques qu'elle pose on stimulerait considérablement son rythme de développement. Parmi les problèmes que l'on pourrait ainsi résoudre citons: la recherche d'espèces convenant à l'élevage; des recherches sur la nutrition des animaux de culture et sur la mise au point d'aliments adéquats; la pathologie

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des animaux de culture; des études sur le comportement de ces animaux; des études techniques; des études sur la pollution et l'utilisation des déchets et des effluents thermiques; des recherches juridiques; des recherches économiques et sociales.

Il est proposé d'établir un petit nombre de centres régionaux d'aquiculture pour y étudier les problèmes les plus pressants.

Se entiende por acuicultura la cría de especies acuáticas útiles controlando de alguna forma los organismos en cuestión y su medio ambiente. Se espera que represente un complemento de la pesca y que permita aumentar en forma significativa el abastecimiento de alimentos proteínicos, pero no es probable que sustituya a la pesca como principal medio de explotación de los mares.

A veces se producen confusiones en los debates por el hecho de que el término acuicultura abarca diversos procedimientos claramente distintos, cuyas probabilidades de transformarse en industrias importantes son también diversas. Un tipo de acuicultura entraña la cría de peces y otros animales en piscifactorías para soltarlos luego en el mar, esperando aumentar así las capturas comerciales. En el caso de la mayoría del enorme número de animales maduros así cultivados, no existen pruebas de que se haya logrado ningún beneficio. Otro tipo de acuicultura consiste en capturar y encerrar formas juveniles, completando su alimentación en diversas formas y grados. Un tercer tipo entraña la producción de alevines a partir de huevos obtenidos de animales capturados. El último tipo de acuicultura, que es el que equivale a la agricultura, entraña la cría de formas juveniles obtenidas a partir de huevos procedentes de progenitores criados por el piscicultor. Los ejemplos de estos dos últimos tipos de acuicultura no son aún muchos.

Las zonas del borde de los mares adecuadas para la acuicultura son enormes; por ejemplo, cerca de 1,5 millones de hectáreas en Asia y tal vez medio millón de hectáreas en Nigeria, por citar uno solo de los países africanos. La producción potencial depende de mucho imponderables, pero se cree que podría ser muy grande, tal vez diez veces superior a la actual.

La acuicultura se ha desarrollado con muy poca ayuda de los científicos, y la solución de diversos problemas técnicos y de ingeniería permitiría acelerar mucho su desarrollo. Entre los problemas que deben resolverse figuran: la búsqueda de especies adecuadas para cultivo; la nutrición de los animales cultivados y la preparación de alimentos adecuados; la patología de los animales cultivados; el comportamiento de los animales cultivados; la ingeniería acuícola; la contaminación y el empleo de desechos y de calor residual; los problemas jurídicos; los aspectos económicos y sociales.

Se propone el establecimiento de un número reducido de centros regionales de acuicultura para estudiar los problemas más urgentes.

TWENTY years ago relatively few marine fish stocks were seriously overexploited, but in the short space of two decades a substantial number of additional populations reached that stage. This trend is certain to continue unless an unexpected wisdom is achieved by the nations of the world, leading to more rational and effective methods of development and management of fisheries. It is to be hoped that this Conference will hasten that day. But in the meantime it is recognized by nearly all experts in the field of fisheries that even under perfect regulation and control the optimum harvest of the sea will provide less food than is required by present, let alone future, populations. Since human affairs are conducted less than perfectly, the amount provided by fishing will fall considerably short.

To an increasing degree, therefore, attention is turned to aquaculture, the techniques of raising useful aquatic species under some control of the organism and its environment. With proper development aquaculture can supplement fishing by adding significant amounts of protein food. It is important to realize, however, that it is highly unlikely that fish culture will ever replace fishing as the principal means of exploiting sea resources; for the moment, the chance is small of raising such substantial quantities of cheap fish that the hunger problem will be solved in any part of the world. Instead, marine aquaculture will add to the total available protein food.

Kinds of Aquaculture

Discussions of aquaculture are often confused because there are a number of distinctly different procedures that are embraced by the term, with different chances of development into major industries.

There are four general types of aquaculture, the first being to raise fish and other animals in hatcheries for release into the sea or lakes with the expectation that natural stocks will be supplemented and commercial or sport catches be improved. The United States was a leader in this activity, followed closely by Canada and other nations, and hatcheries were built in many parts of the world. Beginning in the 1890s US hatcheries turned out large numbers of fry and juveniles of cod, salmon, lobsters, shad, and other species. The theory behind this kind of operation is that, since most of the mortality of aquatic animals takes place during the earliest life stages, stocks can be increased by protecting and feeding them during these stages. The commonly held view was expressed by George M. Bowers, US Commissioner of Fish and Fisheries: ". . . fishing by effective means must be allowed, and a due proportion must be taken from their spawning grounds so that sufficient ova may be touched by the magic wand of protected propagation to provide for future crops."

Unfortunately, the apparently reasonable expectation that wild stocks would be increased by the release of hatchery-raised animals was not rigorously tested in most cases, and in the few where this was done the results were negative. Careful studies by Dr R. E. Foerster of the Fisheries Research Board of Canada on the efficacy of sockeye salmon hatcheries in British Columbia showed that little advantage was gained by artificial propagation, as then practised, over natural spawning. The result was the closing of the many hatcheries in British Columbia, and later in Washington and some other areas. Only in recent years have techniques improved and fish values increased so that hatcheries in the Baltic Sea for Atlantic salmon and on the Columbia River for coho and chinook salmon have been shown to pay their way. Salmon spawning channels also show promise of success. But for nearly all the multitude of other marine and estuarine species raised and released, no proof has been presented that hatcheries have made a worthwhile contribution to wild stocks.

The second kind of aquaculture involves the capture and confinement of young. In enclosures they may be left to fend for themselves, the water may be fertilized to encourage the production of natural food, or supplementary food may be supplied. Most of the successful kinds of estuarine and marine cultivation are variations of this technique. In the Far East, for example, milkfish, mullet, and several species of shrimps are raised in ponds which have been stocked with larvae or young captured in the sea or swept into the ponds by tidal action. This kind of aquaculture may involve complicated preparation of the enclosures, including the culture of mats of algae harbouring a bewildering complex of crustaceans, worms, and other animals. In some of the most successful techniques, animals are held in high densities and supplied with oxygen and supplemental food. Trout, catfish, and shrimps are examples. Oyster and mussel culture are special examples of this kind of culture, the young usually being collected on surfaces put out for the purpose, and varying degrees of care being applied to the growing animals until they are large enough to harvest.

A third kind of aquaculture involves the raising of young from eggs obtained from wild parents, and their retention and feeding in enclosures until they reach marketable size. This is a more complicated technique than either of the first two, and for some important marine species the necessary skills have been attained only in recent years. In particular, it is usually difficult to bring young animals through the larval and juvenile stages. These stages are usually small and delicate, and have very particular food and environmental requirements. Moreover, the cost of holding, feeding, and handling the animals until they attain marketable size is often so high that profitable operations for these species have not been established. This kind of procedure still involves the capture of wild gravid females and (for most species) ripe males, so that it is still dependent to a significant degree on availability of naturally produced animals. Japanese shrimp culture is an example of this kind of aquaculture.

The last and most sophisticated method involves the hatching of eggs, the raising of young in ponds or other enclosures until they reach marketable size, and the maintenance of brood stock. Hence full control is achieved by the aquatic farmer over the life cycle of the animal. This is the only kind of aquaculture that is comparable to land farming and, so far, it is uncommon. In fresh water, carp, trout, and catfish are raised by these sophisticated techniques. So far, the cultivation of no marine or estuarine animal has achieved this level of development, except salmon and oysters on a small scale. In Puget Sound, near Seattle, Washington, pan-sized (half-pound) coho salmon are being raised in ponds. These find a ready market, and in early 1972, 200,000 lb (90,000 Kg) were sold. Rearing Atlantic salmon and trout in sea water is now a thriving business in Norway. Firms on Long Island, New York, have nearly full control over oyster culture, maintaining brood stock, controlling the time of spawning and raising larvae. Only in the last stages is control lost to a degree, since the oysters are planted in Long Island Sound and subsist on natural food.

Potential for Marine Aquaculture Development

TYPES AND EXTENT OF AREA AVAILABLE

Only a limited part of the sea, the shallow region near shore, is suitable for aquaculture activities. The total shelf area constitutes only about 3% of the sea surface and, in most cases, it will be possible to farm only the shallower areas of these, probably less than 30 m.

Nonetheless, there are still enormous areas available for the conduct of aquaculture, especially in the developing areas of the world. Many of these areas are swamp, edge-of-the-sea regions that have been regarded in the past as wastelands.

In only a few areas have surveys been made of the potential area available for aquaculture operations, so that the total over the world can only be hazily guessed. In some Asian countries about 400,000 ha of coastal waters are under cultivation, and a total of 1,500,000 are believed suitable. This calculation does not include Japan, China, or India, three of the biggest countries and those most active in fish culture. In Africa a single country, Nigeria, has at least a million hectares of mangrove area that could be made into sea farms, and it is not inconceivable that half this could be used more profitably for aquaculture than for other uses. There are additional millions of hectares along the edges of other countries in Africa, while South America and many other regions also have enormous areas of coastline suitable for aquatic farms.

POTENTIAL PRODUCTION

It is impossible to give reliable figures for the total production of marine aquatic farms since statistics have not been kept accurately. An estimate for all kinds of aquaculture — fresh water and marine — made in 1972 by the Fish Culture Section of FAO is cited by Pillay in another paper at this Conference: for 43 countries the production of finfish was estimated at over 3.7 million metric tons, with another million tons of shellfish, for a total of 4.7 million tons. This represented about 6% of the catch of marine fish and invertebrates by fishing operations in 1970.

In marine and brackish waters the major culture industries are for shellfish, principally oysters and mussels, with substantial milkfish and mullet production in some Asian countries. In the Far East, several species of shrimp are raised, often in the same enclosures with milkfish. In Japan yellowtail (a large fish) are raised in mesh cages; in 1968 more than 27,000 tons were produced. Other estuarine animals raised include lobsters, clams, abalone, scallops, pompano, and plaice. For most of these species commercial production is insignificant, with the culture of most being still in the laboratory or early pilot stages.

To predict accurately how much present yields could be increased in future years requires data that are not available, and a knowledge of future events impossible to foresee. But the increase could be very large: ten times the present levels is not unrealistic.

RESEARCH AND ENGINEERING REQUIREMENTS

Despite a 4000-year history of aquaculture in China, Japan, and Egypt, over 3000 years in Java and India and at least 2500 years in parts of Europe, most of the present level of skill has been achieved without scientific aid. When present activity of biologists, engineers, and other specialists begins to bear fruit, and current interest in aquaculture stimulates the kind of scientific activity that is sure to follow, fish-farming production will share some of the benefits that have multiplied the yield of land farms in the years since scientists began to solve agricultural problems. Pragmatism, always slow and often only partially successful, can be replaced in aquaculture by the careful analysis of such problems as the siting and design of fish farms; the supply, purification, and oxidation of water; the supply of adequate quantities of stock including the maintenance of brood animals; the supply of cheap and nutritious food; methods of handling, harvesting, and processing the captive animals. Substantial progress in even a few of the technical problems faced by aquaculture could result in considerable increase in the production of marine waters.

The search for species suitable for culture — Fish and invertebrates suitable for commercial culture should have all or most of the following characteristics: they should be fast growing on cheap and abundant food, preferably of plant origin; they should be abundantly and easily available in young stages suitable for stocking enclosures, or they should be capable of being raised from the egg throughout all their stages; they should be resistant to parasites, diseases, and unfavorable environmental conditions; they should have high market value. Few species possess all these characteristics, and hence there will be a relatively small number worthwhile raising commercially. Not all those which are suitable have been identified.

Research on nutrition of cultured animals and development of suitable food — The food supplied to aquatic animals under culture has more often than not been chosen without regard to nutritional requirements. Moreover, many of the natural foods used — such as scrap fish, squid, and ground clams — are not satisfactory because they are hard to handle or are scarce and expensive. In particular, this set of problems refers to the juvenile and young adult stages. Most research in recent years has been directed at larval and postlarval animals, and in many cases biologists have succeeded in identifying the food requirements for the successful raising of shrimp, oysters, clams, and several species of fish from the earliest stages after hatching to advanced postlarval and juvenile stages. But for many species information is lacking for the older animals, up to the time when the crop can be harvested and sold. As they grow larger the kinds of food required change (sometimes more than once). Sometimes slight variations from the optimum are enough to render a culture operation unprofitable; by the same token a little more knowledge will change some unsuccessful industrial aquaculture operations into profitable ones. Some of these problems are beginning to yield to the scrutiny of scientists and engineers. Work by nutritionists has succeeded in producing satisfactory foods for coho and chinook salmon raised in hatcheries on the Columbia River, an accomplishment which is credited with the final success of this operation which has failed for three quarters of a century. Encouraging progress has been made in development of pelletized foods; often using fish meal supplemented by vitamins and other nutrients. Of particular interest is the use of cheap plant food of local origin.

Studies on the economics of feeding and handling — In developing countries the cost of labor for maintaining cultured animals is a principal problem; this is sometimes not the case in other lands, where the necessity for maintaining high employment is preeminent, even at the expense of efficiency. The common present practices of feeding by hand may in many cases be altered to make use of mechanical and demand feeders, with considerable savings in labor and food. Some animals now fed at frequent intervals may prove to grow as well with one feeding a day. A heavy cost in some operations results from the necessity to move animals from one place to another, and to harvest them. Efficient methods of accomplishing these operations would be enough to shift some kinds of aquaculture to the profit side.

Studies of the physiology of maturation and spawning — In some kinds of aquaculture, especially in parts of the world where this activity has the longest history, supplies of eggs and young are obtained from wild stocks. This may support profitable operations for some time to come, but eventually most kinds of commercial culture will require that the fish farmer has control over the full life cycle of his animal. Research is required on the physiology of reproduction and on manipulations by which it is possible to control and induce maturation. Intramuscular injections of pituitary and other hormones are useful for many species. Of great long-term importance is the fact that genetic studies are not possible until the full life cycle of the animals is capable of control. Only then can selection for fast growth, good food conversion, hardiness, and other desirable characteristics be made, and hybridization achieved.

Pathology of cultured animals — Because of the difficulties of making quantitative observations, little is known about diseases of marine organisms. The incidence and intensity of diseases increases when animals are enclosed, and the problem is intensified as densities increase. Yet aquaculture will usually not be profitable except under high density conditions, so that research is required to increase understanding of diseases and parasites of cultured animals, followed by development of control methods.

Studies of the behaviour of cultured animals — Better understanding of animal behaviour can help the aquaculturist. Reaction to crowded conditions differs among species: trout and some other fishes are not adversely affected by crowding, but other animals, including shrimp, stop feeding when they touch another animal. Many animals exhibit feeding rhythms which are associated with light changes, temperature variations or other diurnal or seasonal changes in the environment; understanding of these can be put to advantage by the fish farmer. If they are suitably conditioned, some fish may be maintained without cages or other enclosures; in Japan and the United States trout have been trained to come from considerable distances to feed at the sound of a buzzer. This reaction could also be used to simplify harvesting.

Engineering studies — Research is needed in the design and construction of ponds, cages and other enclosures. Cages promise to be better than ponds for some species, but the size, shape and materials need study. The supply and movement of water is a major problem in commercial aquaculture, and in Japan and elsewhere the cost of power to move water and to supply oxidation has made some culture operations unprofitable. Little information is available on the chemical and physical changes that take place in pools that are fertilized.

Studies of pollution, and the use of waste substances and energy — Water pollution has become one of the major issues of our present society, with good reason, since it poses a threat to many desirable and essential activities. While the human population doubles about every 35 years, the rate of increase of water pollution multiplies six times in the same period. And the shallow waters where virtually all the aquaculture activity takes place are those under the greatest threat of damage by pollution. If the present promise of fish culture fails to be borne out, probably the major obstacle will prove to have been pollution.

Sewage, industrial wastes, fertilizers, hard pesticides like DDT, heated water, silt oil, radioactive substances, and trash all spoil water for culture purposes. Sometimes only exceedingly small quantities of toxic materials need to be present to kill fish or affect their growth and reproduction. Sewage uses the oxygen in water, killing fish or driving them away, and it may carry pathogenetic microorganisms which threaten human health. In the United States, 1.2 million acres of grounds have been closed to the culture of shellfish because pollution has rendered them unfit to eat; in Canada 25% of the potential grounds are closed to harvesting because the water is polluted.

One of the attractive aspects of aquaculture is the possibility of making use of waste materials, especially sewage, and heated water from power plants. Because of variations in the effects produced from the use of sewage, and because of health and aesthetic considerations considerable research is required. This includes studies on methods of partial or complete treatment prior to use in fish ponds, including the amounts to use and the patterns of application. Protection of the cultured organisms and of human consumers against disease and parasites must be sought.

Trials in the use of waste heat from power plant discharge water are in very early stages of experiment. The detrimental effects of heated water on aquatic environments have alarmed conservationists, and a great deal of money is spent to dissipate this heat. But it can be used to advantage if the water can be fed to ponds where fish are being raised. Growth of fish in ponds at Konin, Poland, was two to three times as great in water whose temperature was raised 6–10C above ambient by the heated effluent from two coal-burning power plants. In Britain, plaice were grown to marketable size in half the normal time in ponds heated 7C above ambient temperature by power plant effluents. These are only tentative first essays into a complicated matter, and we should not be misled into believing that fish farms can solve the waste heat problems caused by power plants; yet some of the energy otherwise wasted can be utilized if proper conditions exist and adequate planning is done in the design of aquaculture and power installations.

In addition to biological and mechanical problems, which are tractable to solution by appropriate scientific and engineering scrutiny, there are other constraints, legal, economic and social, to the realization of the full potential of aquaculture. These may be more significant than the technical difficulties.

Legal research — Legal impediments to aquaculture development are numerous and perplexing in some areas — so much so that often it seems impossible for culture industries to develop. This is partly because the body of law has grown up without taking aquaculture into account — there being none to consider as a rule. Moreover, where aquaculture does exist, competing interests have usually been stronger, and laws reflect this. Rights to the use of public waters are extremely complex and so far the attendant problems are unresolved.

Economic and social research — At least in developed countries the major barrier now standing between laboratory or pilot-scale aquaculture operations and industrial activities is economic: while it has been shown that a number of species of animals can be raised to market size under culture, most of these cannot be produced profitably. In some cases this is because the operations have not been scaled up so that a sufficient volume of product results. Studies of costs would identify economic bottlenecks and focus on areas requiring more attention.

Social problems pose greater difficulties than any others to the development of aquaculture in some areas of the world. Shoreline property has had a higher value than other land in most parts of the world, especially in developed countries. This is partly because human populations tend to crowd along shorelines: seven of the world's largest cities are on estuaries, and over half the world's population lives within 100 miles of the sea. In the United States one-third of the population lives in coastal counties, and one-third of its industry is located there.

Aquaculture in many regions, a relatively latecomer to the group of activities needing shoreline space, is often at a strong disadvantage in competing with commercial and sport fishing, swimming, boating, oil and other mineral exploration, and waste disposal. For example, an ambitious operation designed to raise penaeid shrimps in Florida was severely handicapped in its development plans because of opposition by several groups of residents in the area. Commercial shrimp and mullet fishermen protested the closing-off of part of the coastal region to their operations. Boaters and sport fishermen claimed rights to free passage through the coastal region. Conservationists objected to the shrimp farming activites because they feared damage to the estuarine environment by poisoning of the enclosed waters prior to stocking, and to alterations in the water current pattern and other aspects of the environment. Only with great difficulty was a compromise agreement reached which permits the culture operation to proceed. In California and Washington, attempts to establish suspended culture of oysters was prevented because residents living around the bays objected to the presence of the rafts on grounds that they were unsightly, and that they interfered with navigation and other activities. These kinds of attitudes are so prevalent in the United States that the future of many kinds of coastal aquaculture there is uncertain. To a greater or lesser degree the same problems occur in other parts of the world.

In certain areas of some developed countries, even where local attitudes favor the development of aquaculture activities, it may prove to be uneconomic to establish these industries because of the high cost of land. The aquatic farmer competes with housing development, construction of power stations, other industrial structures, and recreational activities.

Conclusion

The role of research in promoting agriculture is familiar; without the intensive work of research centers land farming would be significantly farther behind in efficiency and the world enormously poorer in supplies of food. Aquaculture requires research to no less extent than land farming, indeed it may be said to have even a greater requirement for assistance. As complicated as land animals are, the biology and ecology of aquatic animals are often more difficult to unravel.

Research at a high level of sophistication is thus required to solve aquaculture problems, and this should be encouraged in as many places as possible. In addition, a small number of large, specialized centers of aquaculture research should be established in suitable places in the world, where specialists in several branches of science and engineering can be assembled to focus sharply on the most pressing research tasks. The concept of minimum critical mass has been shown to apply to research groups, where a number of competent scientists working together can produce far more tangible and useful results than the same number scattered in many institutions. This is not a plea for centralizing aquaculture research, but instead is a suggestion that the knowledge required to advance the productivity of this activity could be enhanced significantly by a small number of well planned, carefully oriented, suitably staffed, and adequately financed research centers.

Productivity of the Oceans[1]

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The ratio of total world fish landings to annual primary production, about 1:3000, suggests a poor exploitation of the biological productivity of the world ocean. The ratio ranges from 1:100 in the most intensively exploited shelf areas and coastal upwelling regions to beyond 1:100,000 in the central oceanic gyres. Regional differences are a thousand-fold higher in fishing yields than in primary production.

The yield differences among areas are caused by three groups of factors: 1, Primary production, which is subject to environmental factors; 2, Length, structure, and transfer efficiency of the food chain, which connects the primary producers with the exploited fish population and determines the ratio between fish production and primary production. Wherever primary production is high, the ratio tends to be favorable, particularly in shelf and upwelling areas. The short pelagic food chains of the cold-water regions lead to rich exploitable resources of pelagic fish, whales, and krill; 3, The rate of exploitation of the fish resources. The ratio between potential production and the actual yield is poor in areas with low fish production, where exploitation is difficult and expensive.

Any attempt to increase world fishery yields aims at a change of one of the three groups of factors. Artificial changes in primary production are of local importance only. They are possible through discharge of nutrients and waste energy. Changes in the length and structure of food chains are achieved through a shift of interest to abundant groups of organisms that are closer to primary production. Exploitation of krill and the mass culture of mussels are promising examples. Increases in the exploitation rate can be achieved through better adjustment of fishing to population dynamics of heavily exploited stocks and through extension of pelagic fisheries, particularly in certain parts of the southern hemisphere and the open ocean.

Le rapport entre les mises à terre mondiales de poisson et la production primaire annuelle, qui est d'environ 1:3000, donne à penser que la productivité biologique des océans du monde entier est médiocrement exploitée. Ce rapport varie entre 1:100 dans les régions côtières d'upwelling et les zones de plateau continental les plus intensivement exploitées et 1:100,000 dans les parties centrales des océans. Les différences régionales sont un millier de fois plus fortes dans le domaine du rendement halieutique que dans celui de la production primaire.

Les différences de rendements d'une zone à l'autre sont imputables à trois catégories de facteurs: 1, La production primaire, qui dépend des facteurs écologiques; 2, La longueur, la structure et l'efficacité de transfert de la chaîne alimentaire qui relie les producteurs primaires aux populations ichtyologiques exploitées et détermine le rapport entre la production de poisson et la production primaire. Partout où la production primaire est élevée, le rapport tend à être favorable, en particulier au-dessus du plateau continental et dans les zones d'upwelling. Les courtes chaînes alimentaires pélagiques des régions d'eaux froides donnent lieu à de riches ressources exploitables de poissons pélagiques, de baleines et de krill; 3, Le taux d'exploitation des ressources ichtyologiques. Le rapport entre la production potentielle et le rendement effectif est médiocre dans les zones où la production de poisson est faible et où l'exploitation est difficile et coûteuse.

Toute mesure visant à renforcer les rendements halieutiques mondiaux tred à modifier l'un de ces trois types de facteurs. Les transformations artificielles de la production primaire ne revêtent qu'une importance locale. Elles ne sont possibles que par l'introduction dans le milieu aquatique d'éléments nutritifs et d'énergie résiduaire. Pour modifier la longueur et la structure des chaines alimentaires, il faut orienter l'intérêt vers les groupes abondants d'organismes plus proches de la production primaire. L'exploitation du krill et la mytiliculture massive en sont des exemples prometteurs. Il est possible d'augmenter le taux d'exploitation en améliorant l'ajustement de la pêche à la dynamique de population des stocks fortement exploités et en renforçant les pêcheries pélagiques, en particulier dans certaines parties de l'hémisphère sud et des eaux océaniques libres.

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La relación entre las descargas mundiales totales de pescado y la producción primaria anual, que s edel orden de 1:3000, indica que apenas se explota la productividad biológica de los océanos mundiales. La proporción va de 1:100 en las zonas de la plataforma continental más intensamente explotadas y en las regiones costeras de afloramientos a más de 1:100,000 en los giros oceánicos centrales. Las diferencias de rendimiento pesquero de una región a otra son mil veces superiores a las diferencias de producción primaria.

Las principales diferencias entre diversas zonas se deben a tres grupos de factores: 1, La producción primaria, que depende de factores ambientales; 2, La longitud, estructura y eficiencia de la cadena alimentaria, que vincula a los productores primarios con la población explotada de peces y determina la relación entre la producción de pescado y la producción primaria. Cuando la producción primaria es elevada, la relación tiende a ser favorable, especialmente en las zonas de plataforma y de afloramientos. Las cadenas alimentarias pelágicas de poca longitud que se encuentran en las regiones de aguas frías dan lugar a abundantes recursos explotables de peces pelágicos, ballenas y eufasiáceos; 3, El ritmo de explotación de los recursos pesqueros. La relación entre la producción potencial y el rendimiento real es mala en las zonas de escasa producción íctica, donde la explotación es difícil y costosa.

En todo intento de incrementar el rendimiento de las pesquerías mundiales se aspira a modificar uno de estos tres grupos de factores. Los cambios artificiales de la producción primaria no tienen más que importancia local. Pueden conseguirse descargando sustancias nutritivas y energía sobrante. Para variar la longitud y la estructura de la cadena alimentaria basta concentrar la atención en grupos abundantes de organismos más próximos a la producción primaria. Como ejemplos prometedores pueden citarse la explotación de los eufasiáceos y el cultivo en masa de mejillones. El ritmo de explotación puede aumentarse ajustando mejor el esfuerzo de pesca a la dinámica de los grupos intensamente explotados y ampliando las pesquerías pelágicas, especialmente en algunas zonas del hemisferio sur y de la alta mar.

"PRODUCTIVITY of the oceans" has different meanings to the various groups interested in marine science and exploitation. The term productivity is often used to describe the rate of actual production of certain groups of organisms; it means also the potential rate of production under certain conditions. Biologists are mainly familiar with productivity in terms of primary plant production by phytoplankton and (to a lesser extent) by macrophytes (seaweed and eelgrass) and microphytes (diatoms) covering the seabed in shallow waters. Production at the higher trophic levels of herbivores and carnivores is far more difficult to measure, either directly or through extrapolation since knowledge of the rate of transfer of organic matter and energy from plants to animals and between higher trophic levels is limited to very few sets of data, mainly from laboratory experiments. Economists are interested in the small fraction of marine production harvestable by man. While good statistics of landings are published by FAO and by many regional and national authorities, the quality of predictions of potential landings varies considerably. Assessments of optimal sustainable yields are available for only a limited number of fish stocks. Global figures for the world ocean are of little value for economists who need information on the possibilities of exploitation of specific regions and kinds of marine organisms.

Stock Analysis and Biological Production as Measures of Exploitable Productivity

Estimates of marine resources in terms of annual potential production start either from fishery statistics and resource surveys or from data on primary production and biomass of plankton and benthos. Both kinds of estimates suffer from shortage of reliable data. They are based either on models of dynamics of fish stocks or of food webs. These models are approximations of very different quality.

The first type of approach was chosen by the advisory group on the marine fisheries resources aspects of the FAO Perspective Study of World Agricultural Development (PSWAD), (formerly IWP) (Gulland 1972). The bases for the estimates were extrapolations of landings of certain fisheries. Results of exploratory fishing, echo-surveys, and egg and larval surveys provided the estimates of size of unexploited and little exploited stocks. These estimates together with assumptions on natural mortality were used to assess the potential sustainable annual yield, which, in many cases, may amount to a quarter or a fifth of the virgin stock. For technological and economic reasons, the yield will remain below the maximum potential, especially in mixed fisheries and in oceanic areas. Mathematical models of the productivity and optimum sustainable yields of exploited fish populations were applied in cases where sufficient data were available on average growth and on natural and fishing mortality. In areas for which too little was known of exploitable stocks, the size and topography of the shelf and data on abundance of plankton and benthos were used to draw analogical conclusions to better known exploited areas. These analogies are of limited value where knowledge of the structure of ecosystems is small.

Biological oceanographers, particularly Bogorov and Rass (1961), Dickie (1972), Ricker (1969), Ryther (1969), Cushing (1969), and Schaefer (1965), estimated fish production using the second approach on the basis of information on primary and secondary production. Moiseev (1969) tried to link both approaches. On one hand he based estimates of potential fishing yields on detailed considerations of primary production and transfer efficiencies in various zoogeographic regions; on the other hand, he summed up the potential harvests of individual areas and fish stocks on the basis of past and present fisheries statistics. As a supplement to the economically orientated contributions and discussions at the Technical Conference on Fishery Management and Development, the present paper will summarize part of the present knowledge in biological oceanography applicable to assessments of the resources of the sea exploitable to fisheries.

Regional Differences in Marine Production

For any given area, productivity of exploitable stocks depends on primary production, trophodynamics of ecosystems, and exchange of organic matter with other areas. Furthermore, fisheries have direct effects as well as indirect ones. Among the direct effects, the changes in age structure and recruitment are most important; indirect effects include changes in the ecosystems through upsetting of the predator-prey relations and competition for food, possible destruction of habitats by trawling, etc., and causing nutrient limitations to the ecosystem.

For purposes of fishery resources prediction and management we have to consider the sea as a mosaic of ecosystems with different ratios of primary production to exploitable production. Global figures of annual primary production given by several authors (for summaries see Koblentz-Mishke et al. 1968) are of little use in view of the vast regional variation in ratios, as demonstrated by the following examples.

The total landings of 60 million tons of marine organisms in 1971 equal a global average yield of 0.17 tons/km^2, while in the North Sea the annual yield is above 6 tons/km^2.

Moiseev's (1969) map of the catches of world fisheries in 1966-67 shows five areas of the northern hemisphere with catches exceeding 3 tons/km^2 (North Sea, Iceland, southwest Greenland, Newfoundland, southeast coast of USA, eastern Bering Sea). All those areas are shelves where demersal fish play an important or even dominant role; the same is the case for other important fishing regions of the western and eastern boreal Atlantic Ocean and the western Pacific Ocean. In the southern hemisphere, yields of more than 3 tons/km^2 are confined to only two areas, Peru and southwest Africa. While off Peru the shelf is extremely narrow and virtually all landings consist of pelagic fish, the situation off southwest Africa is characterized by a relatively wide shelf area with demersal and coastal pelagic fish, which profit from a high primary production due to upwelling. At present no other large area of the southern hemisphere yields more than 1 ton/km^2 per annum. Wide shelf areas are scarce in the higher latitudes of the southern hemisphere.

Annual catches in open ocean areas are mostly less than 0.01 ton/km^2. Exceptions are some northern North Atlantic Ocean fisheries for herring, capelin, and blue whiting, and from warmer ocean waters for tuna-like fishes. Fisheries for squid, sauries, salmon, and others in the North Pacific Ocean extend from coastal waters into the open ocean.

The difference between the landings from rich shelf areas and the open ocean is a thousand-fold, even ignoring extreme values.

Compared with the great regional differences in landings, averages of annual primary production differ little. Highly productive shelf areas of the temperate zone show means of annual production of 50-300 g carbon per square meter (gC/m^2). For coastal boreal areas with high supply of nutrients those values can be somewhat exceeded. In the southern ocean, Ryther (1969) estimated an annual overall average of 100 gC/m^2, which is presumably an overestimate when considering the positive bias in the selection of observation sites. In coastal upwelling areas in domes of nutrient-rich water in low latitudes, primary production reaches 300 gC/m^2. However, the sizes of those highly productive areas are small.

The vast oceanic areas of tropical and subtropical regions produce 10-50 gC/m^2. These figures are rather unreliable, particularly regarding the lowest values. The difference in primary production between the highly productive and the poor areas of the world ocean is less than two orders of magnitude; possibly, it does not exceed the factor 20.

The discrepancy between the ranges of variation in fish landings and primary production is well reflected by the regional differences in the ratios between the fishing yields and the primary production. In the North Sea the ratio is about 1:100 (figures by Steele 1965 and Gulland 1970, adjusted to recent catch data). In the Sea of Japan, the ratio is about 1:700, in the Sea of Okhotsk about 1:1000. For the Gulf of Thailand, a highly productive tropical shallow sea, the daily exploitable fish production is of the order of 0.001-0.002 gC/m^2. Daily primary production might be about 0.5 gC/m^2, giving the ratio of about 1:300. In the Peruvian upwelling area fishing yield averaged 10 million tons, equal to approximately 0.01 gC/m^2 in the late 1960s, which again gave a fishing yield to primary production ratio of 1:100.

In the open tropical and subtropical ocean, with an annual primary production of at least 4×10^9 tons carbon, about 1.6×10^6 tons of fish are landed, the ratio in carbon units being 1:25,000. No relative estimates can be made for those areas where fish stocks migrate to and from between shelf regions and the open ocean, as is the case in Atlanto-Scandian herring and possibly redfish (*Sebastes*).

Causes of Regional Differences in Production

Environmental and biological factors that determine the abundance, production, and diversity of food fish are the most important limitations to the long-term expansion of world fisheries. Quantitative interrelations between the fish stocks and their environment are little known even for those areas with a long history of fishing and marine research (Dickie 1972).

HYDROGRAPHY AND PRIMARY PRODUCTION (see Laevastu and Hela 1970)

Hydrographical factors influence the distribution of fish stocks. Direct adverse effects of temperature on overall abundance of fish are noticed in polar seas; areas of less than 1 C are generally poor in fish. Otherwise, the influence of temperatures normally observed in the sea are more of an indirect nature, affecting food-web structure and rates of energy flow. There is, however, little information on fish production versus fish abundance comparing areas with different temperatures. Direct effects of salinity are small except for brackish water areas. Oxygen deficiences are restricted to relatively small areas (e.g. Black Sea, Baltic Sea, certain coastal upwelling regions), or to depth layers of little importance to exploitable fish populations. Indirect effects of hydrographical factors on fisheries are most obvious in upwelling regions. Cushing (1969) and

Murphy (1972) have summarized present knowledge on potential yields in the coastal upwelling areas off the west coasts of Africa and America. Large-scale cooperative studies in coastal upwelling zones presently aim at a better understanding of the physical process involved and chemical and biological effects. It is evident that changes in the atmospheric pressure field determine fluctuations in intensity and extension of upwelling. The topography of the shelf and the continental slope as well as the pattern of internal waves and of tidal currents have additional effects. Both velocity and depth range of the vertical transport determine largely the supply of nutrients and their utilization by phytoplankton (Dietrich 1972). Horizontal movements and the mixing processes of oceanic upwelled and coastal water masses determine spatial distribution, abundance, and diversity of phyto- and zoo-plankton. The higher levels of the food web depend largely on continuity or seasonal discontinuity of physical processes of upwelling (see below).

SHELF AND BENTHOS

Benthos in addition to plankton is used by many fish as a second or even the main source of food. Daily benthos production per unit area is generally lower than in zooplankton. However, the much longer life span of many benthos organisms resulted in large and stable standing stocks that can be "economically" exploited by large bottom-dwelling fish, which in turn provide the basis for profitable fisheries. In the cold and temperate zones, neritic (shelf-living) pelagic fish can cope with the strong seasonal variations in zooplankton abundance by storing large amounts of fat for the poor season.

There is a general increase in zoobenthos from low latitudes toward the poles. On average, soft-bottom habitats of temperate seas are occupied by benthos biomass that is ten times higher than in tropical areas. However, production rate of macrobenthos in the temperate zone is much lower than in the tropics. In many areas only 20–30% of macrobenthos is potential food to fish. Echinoderms and hard-shelled molluscs are useless, except for a few species (e.g. haddock) that eat echinoderms. Even of the good food items, the majority might be eaten by noncommercial carnivores such as starfish. In two neighboring areas, the Kattegat and Kiel Bight, the utilization of benthos by commercial fish was shown to be different from each other (Arntz and Hempel 1972). In the Kattegat, echinoderms predominate and total consumption by food fish is assumed to be 1–2% of benthos production, while in the Kiel Bight with its rich mollusc fauna consumption by fish is at least 30% of the total benthos production.

The abundance and composition of benthos of the deeper parts of the continental slope and of the abyssal plain are very unfavorable for most fish. In 1000–2000 m, sponges show maximum abundance; in the deeper regions starfish, actinia, and ultimately holothurians predominate. More than 80% of zoobenthos biomass of the ocean are concentrated to the depth of less than 200 metres. The North Sea, the western Baltic Sea, the Asow Sea, Newfoundland waters, Japanese waters, the Bering Sea, and the Gulf of Alaska are listed among the regions with more than 200 g/m^2 zoobenthos mass and with high fish landings (Moiseev 1969). On the other hand, very cold areas, which are poor in commercial fish, can be particularly rich in benthos. According to Zenkevich et al. (1960), figures of benthos biomass per square meter are four orders of magnitude higher for shallow water benthos than for the deep sea. A few exceptions can be found in deep-sea areas bordering highly productive shelf zones. It is only here that appreciable amounts of living and dead organic matter reach the deep-sea bottom, either through passive sinking and turbidity currents or through active transport by vertical migration of predators. In deep-sea benthos only organisms in the millimeter-size category ("meiobenthos") are relatively abundant and productive (Thiel 1972). Meiobenthos, however, is of little importance as food of fish, except for sediment feeders. Estimates of world production of benthos are very unreliable; too little is known about the ratio of production to biomass in benthos communities and the exploitation of benthos by fish. Moiseev (1969) estimated a total world benthos production of $1\text{–}2\times10^9$ tons. Because a great part of it consists of "useless" organisms and another part is produced in nonaccessible polar areas, benthos production used by commercially exploitable fish will be far less than 1×10^9 tons.

If one assumes an annual consumption of 500×10^6 tons of benthos by fish and a conversion rate of 10%, 50×10^6 tons of fish may be produced on benthos food only, most of it (90%) in shallow shelf regions. The present world landings of demersal fish and crustacea are about 25×10^6 tons per year.

Although the seaweed belts and eelgrass meadows are relatively small, their contribution to the marine primary production is appreciable. According to Ryther (1969), 0.1% of the sea floor produces almost 2% of marine plant matter. The highest biomass of 20 kg/m^2 is found in the boreal kelp forests. However, phytobenthos is generally of little importance as food of commercial fish. Seaweed, kelp, and carpets of diatoms are not eaten to any extent except by milkfish, coralfishes, and mullets. Its major ecological role lies in the provision of shelter and substratum. For possible future increase of direct exploitation and culture of seaweed, reference is made to a recent review by Michanek (1971).

COMPLEXITY AND TRANSFER EFFICIENCY OF PLANKTONIC FOOD CHAINS

Striking differences exist in the length and complexity of food chains that connect exploitable fish populations with primary production.

Size and abundance of food and its seasonal changes determine the kind of predator. In oceanic waters, particularly of lower latitudes, the main primary producers are the flagellates and other nanoplankton, which are mainly used by microzooplankton such as radiolarians. These are the food of carnivorous crustacea, particularly copepods and euphausiids that, in turn, are the staple food of pelagic fish. In coastal waters, in upwelling regions, and in the antarctic most primary producers are larger, mainly consisting of diatoms. Those can be eaten immediately by large herbivorous or omnivorous crustacea. Under these circumstances, the food chain is shorter (Parsons and LeBrasseur 1970). In general, body size and life span increase with the trophic level. At a given size category of food, large organisms require a higher abundance of food, at least in certain seasons; on the other hand, they can store organic matter for long periods. Shortcuts of the food patch in terms of large organisms feeding directly on small food are rare. They can only be found in regions with very high abundance of food almost all the year round (anchoveta in Peruvian upwelling region) or in the cases where food is extremely abundant in summer and the predator has provisions to store large reserves for the winter (baleen whales feeding on krill in the antarctic). However, even in those cases of specialization remnants of the normal food chain structure can be observed whenever anchoveta feed on zooplankton and northern baleen whales feed on small fish.

Most fish do not remain at the same trophic level all their life. The magnitude of recruitment (year-class strength) is mostly fixed at a time when fish are microzooplankton feeders. Most juvenile fish (e.g. young cod) shift to macrozooplankton including crustacea living near the sea bed (hypoplankton) or to invertebrate benthos that feed partly on detritus, bottom diatoms and phytoplankton, and partly on animals. A major part of fish growth takes place during this period. Subsequently the cod moves up by at least one more step in the food chain by becoming a fish feeder. Reduction of old fish by heavy exploitation means reduction of individuals at the high trophic levels. Old fish compete with man in the predation on young fish.

Recently Kerr and Martin (1970) have demonstrated how food abundance and size of food influences the structure of food chains and their energy transfer. They compared the fish production in two food chains with trout as ultimate predator in oligotrophic lakes. In one lake, trout fed on zooplankton; in the other, the trout were fish feeders. In spite of difference in length of food chain, the overall trout production was about the same in both. Efficiency increased with size of forage animals and individual trout became larger when feeding on fish. Conversely, larger organisms are somewhat protected against predation. Dickie (1972) points out that "under the influence of predation, size increase must have a strong selective advantage."

The production/biomass ratio in a balanced population may be defined as the turnover rate and vice versa. The average growth rate of the biomass of the population equals the losses by total mortality and determines the ratio of production to biomass. The ratio is different at different trophic levels and determines the complexity and efficiency of food chains. High food conversion and ecological efficiencies are not necessarily final "goals" of ecosystems. This fact limits predictions of production on high trophic levels.

These considerations do not include the additional limitations to fish production caused by the competition of "useless" organisms and the transfer of energy into "blind alleys," which are well-known for benthos but are also important for plankton wherever coelenterates and chaetognaths are abundant.

In a nutrient limited ecosystem the "useless" organisms could serve as a buffer against exhaustive exploitation. Hamley (personal communication) points out that most current estimates of potential fish yield are based on the assumption that the exploited ecosystems are energy-limited. He assumes that many important fish communities may live in nutrient-limited systems. In those systems harvestable yield may depend on supply of nutrients, not on supply of energy or on efficiency of the food chain. The yield of protein may be rather similar regardless of trophic level harvest. The results of Kerr and Martin (1970) regarding the two types of trout lakes may be interpreted in this way. Exploitation of nutrient limited ecosystems means depletion of the overall pool of nutrients in the system, and sustainable yields should not exceed the nutrient supply from outside minus the 'leakages' (loss of nutrients to deep waters and sediment). Cushing (personal communication) stresses that as minimum nutrient concentrations for primary production are rather low, effects of eutrophication in the sea are difficult to understand. I assume that intensive grazing, and hence increasing of the euphotic zone, results in an overall increase of primary production making use of the surplus nutrients. The interaction between nutrient supply, productivity, standing stock, and compensation depth together with seasonal changes thereof leads to the assumption that purely nutrient limited or purely energy limited ecosystems are rare extremes of a broad spectrum of ecosystems in which both factors together with water movements, structure of ecosystem, and degree of isolation of the system play their role. That may explain the relatively wide scatter in the relationship between primary production and fish yield.

POLLUTION AND AQUACULTURE

There are few reliable observations on the effects of pollution on exploitable productivity of marine habitats. Although the biological consequences of increasing primary production by eutrophication of certain areas – mainly semienclosed bodies of water – are inevitable, quantitative relations between input of nutrients and yield of fisheries have not been described. The same holds for the effect of heated waste water and of toxic substances. In many cases changes in productivity may result from impoverishment of ecosystems rather than from simple changes in primary production and growth rate. The cultivation of fish and crustacea in seawater ponds with artificial feeding has little to do with using the productivity of the sea (except for the provision of fry and of trash food from the open sea). On the other hand the extensive farming of molluscs along the coasts of several countries and the fattening of several kinds of marine organisms in tropical and subtropical lagoons have to be considered as a very effective use of marine primary and secondary production. In many cases those cultures use not only the local production but also plankton and detritus carried by tidal currents into the culture area. Studies are underway in several parts of the world to estimate the food demands of various kinds of culture organisms. First results were summarized at the Symposium on Marine Food Chains sponsored by FAO, ICES, and ICNAF in 1968 (Steele 1970), indicating the great importance of optimum (not maximum) food supply and, hence, optimum ratio between density of cultured populations (including, e.g. the size of rafts for mussel, oyster, and algal culture), currents, and density of food items.

Conclusions

Sustainable fishing yields in a given area are determined by the following factors: supply of energy and nutrients to the primary producers, length and structure of food chains (particularly important in energy limited systems), ratio of fish production to primary production, and ratio of fishing yield to fish production (exploitation rate). Each factor is different in the different areas of the oceans and shelf seas. The factors are linked with each other.

Any attempt to increase fishing yields in an area is connected with the attempt to change one of the above factors; large-scale increases in primary production, through fertilization or vertical mixing of water masses, or both, are difficult to achieve except in semienclosed sea areas. Waste material and inexpensive (waste) energy are the only means economically feasible. The effects of such measures on food chain structure and production efficiency should be considered in advance.

Little can be done to improve the food chain structure; weeding of useless or harmful organisms is expensive and pays in aquaculture only. A shift toward the exploitation of a wider range of organisms below the top of the food ladder is recommended in energy limited systems. The recent striking increase in exploitation of planktophageous pelagic fish and of small demersal fish are steps in that direction, which in future must be followed by the exploitation of krill, lantern fishes, and other oceanic resources as well as by the cultivation of bivalves.

Good prospects exist in several areas to improve the ratio between exploitable production and primary production. Intensive research in biological oceanography is needed to narrow the wide gap between primary and final production usable by man. At present it is impossible to predict how far this approach can be carried.

The exploitation rate is largely determined by political factors (e.g. national fishing borders), technical factors (e.g. trawlable grounds, dispersal of fish over a large volume of water), and economical factors. There is a difference between actual and potential fish production whenever fishing intensity and size selection of fish (e.g. through mesh size) is not properly adjusted to the dynamics of the exploited stock. All recent assessments indicate that improvements in exploitation rates of "conventional" resources could almost double present world fishery production. Furthermore, better use could be made of most of the catches by drastically reducing the waste caused by microbial spoilage and by processing. Aquaculture, transplantations, and artificial stocking of certain areas are among the possible positive man-made effects on fish production. Although their importance is small for mass production of relatively inexpensive fish protein, they will contribute to the production of high-priced sea foods.

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Objectives and Methods of Small-Scale Fisheries Development[1]

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Governments in industrialized as well as developing countries have adopted policies of assistance for small-scale fishermen. These may be conceived within the framework of social assistance or of purely economic development, but in either case the actions taken need to conform to long-range planning. Care should be taken to see that small-scale fisheries will have a continuing resource base and will complement rather than be in conflict with the activities of large fishing vessels, where the latter exist. In developing countries the objectives and methods used to stimulate the small-scale sector are more varied than in industrialized countries. In the latter, action has been focused mainly on loans and subsidies for modernization of equipment and provision of dock facilities. Less often, roads and even townsites have had to be developed. In developing countries all these may be needed, and they start from a much lower base in terms of equipment and mechanical skill. In addition there is a need for developing marketing facilities, ice plants and refrigeration at major centers, and also training programs, not only for fishermen but also for ancillary services, especially motor mechanics. Frequently the organization of cooperatives is the means by which some or all of these measures are attempted, but here too the necessary managerial skills take time to develop.

Dans les pays industrialisés comme dans les pays en développement, les gouvernements ont adopté des politiques d'assistance aux petits pêcheurs. Celles-ci peuvent être conçues dans le cadre d'une assistance sociale ou d'un développement purement économique mais, dans les deux cas, les mesures prises doivent être conformes à une planification à longue échéance. Il faut s'assurer que les petites pêches seront alimentées par des ressources durables et, le cas échéant, compléteront les activités des grands navires de pêche plutôt que d'entrer en conflit avec elles. Dans les pays en développement, les objectifs définis et les méthodes utilisées pour stimuler le secteur de la petite pêche sont plus variés que dans les pays industrialisés. Dans ces derniers, les initiatives prises dans le même sens consistent principalement en l'octroi de prêts et de subventions pour la modernisation de l'équipement et en l'aménagement de bassins portuaires. Moins souvent, il a fallu construire des routes et même prévoir des sites urbains. Dans les pays en développement, il se peut que la totalité de ces éléments soit nécessaire et le point de départ est plus bas en ce qui concerne l'équipement et les compétences mécaniques. De plus, il faut mettre sur pied des services de commercialisation, des usines à glace et des installations de réfrigération dans les principaux centres, et formuler des programmes de formation, destinés non seulement aux pêcheurs mais aussi au personnel des services auxiliaires, en particulier les mécaniciens. Fréquemment, le dispositif utilisé dans les tentatives d'application de certaines ou de la totalité de ces mesures consiste en l'organisation de coopératives, mais, là aussi, il faut du temps pour former les spécialistes nécessaires en matière de gestion.

Los gobiernos de los países industrializados, así como de los que están en vías de desarrollo, han adoptado normas para ayudar a los pequeños pescadores, que pueden relacionarse con la asistencia social o con la economía, pero en ambos casos las medidas tomadas deben ajustarse a la planificación a largo plazo. Debe tenerse cuidado de que la pesca en pequeña escala se base en un recurso continuo y sean complementarias, en vez de antagónicas, de las actividades de los pesqueros grandes.

En los países en desarrollo los objetivos y métodos empleados para estimular al sector de pequeña escala son más variados que en los países industrializados. En estos últimos las medidas tienen por objeto principalmente facilitar préstamos y subsidios para modernizar el equipo y construir instalaciones portuarias. Con menos frequencia, se han tenido que construir carreteras e incluso complejos urbanos. En los países en desarrollo puede que todo ello sea necesario y parte de una base más baja en lo que a equipo y pericia mecánica se refiere. Además hay necesidad de perfeccionar los medios de mercadeo, fábricas de hielo y frigoríficos en los centros más importantes y de programas de capacitación, no sólo para los pescadores, sino para los que prestan servicios auxiliares, especialmente los mécanicos. Con frecuencia la organización de cooperativas constituye un sistema mediante el cual se intentan realizar todas estas medidas, pero también en este caso hace falta tiempo para preparar dirigentes.

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SMALL-SCALE fisheries are usually defined as embracing all coastal, estuarine, lagoon, river, and lake fisheries, including aquaculture. Characteristically the capital investment in each unit is small, with a correspondingly low level of organization. Specialized mechanical skills usually play little part, although good seamanship may be required. Vessels are small and are predominantly individually owned; and fishing relies heavily on labor-intensive, as opposed to mechanical, methods of handling the gear. The fishing gear itself is sometimes specialized and it may demand great skill in construction or operation. However, both productivity and incomes are usually low. Catches are disposed of in local markets or even on a communal barter basis, so there is usually a lack of infrastructural backing and credit.

In terms of manpower, the world total for full and part-time fisherman in this sector has been estimated by FAO to be in the neighbourhood of 10 million persons. In some societies they are regarded by other members of the community as unprogressive, uncreditworthy, stubborn, or even socially inferior. It is little wonder, therefore, that there are as yet few examples of successful development programs and projects in this sector. Both developed and developing countries tend to be more attracted to the higher returns, both economically and in terms of landings, from more industrialized fishery development.

General Considerations and Past Experiences

The developing countries, normally having need for external capital for development and lacking industrialization and a well-developed financial and administrative machinery, have by far the greatest proportion of small-scale fisheries. In the developed countries this sector generally consists of purely local fisheries, poorly developed in the economic sense, in a setting of well utilized natural resources and a plentiful supply of capital and skilled labor. Or it may include many part-time fishermen who either have alternative employment or are harvesting particularly valuable species. Examples of both these types can be found in Japan, North America, South Africa, and western Europe.

It may be argued that with growing facilities for education, the reluctance of youth to follow their fathers' occupations, and the constant drift of labor to the towns seeking less onerous employment than fishing, especially in developed countries, there is no need to devise special plans for improving these small-scale fisheries, since the pace of other developments will solve the problem (where one exists) by virtually eliminating the less progressive and traditional sector. Although this argument is to a certain extent true, it is not likely to apply to most developing countries for a considerable time yet, and where they are highly populated perhaps never. Very large numbers of small-scale fisherman today have, however, little or no reasonable prospect of improving their livelihood.

There is thus a widespread desire to find solutions to the problems associated with raising the standard of living of these fishermen. Because of its much greater importance to developing countries, the problem of the fishermen who lack alternative employment opportunities merits priority consideration. Solutions should meet both short-term and long-term policy objectives. In this connection it is believed that artificial "preservation" of marginal fisheries should not be accepted as a legitimate long-term development target, and certainly not if it interferes with more productive fishing methods. Existing gaps between developing and developed countries will narrow only as individual branches of the economies of the former become competitive. In cases where there is little or no prospect that small-scale fisheries can be developed to the point of competing effectively without requiring protection of a kind that seriously distorts factor allocation, adjustment policies must not seek to prevent a natural "withering away." In these instances the "development" of such groups of small-scale fisheries should be conceived within the framework of transitional policies aimed at bringing the rate of withdrawal from this sector into line with the opening-up of opportunities for manpower in more productive branches of fishing or in other industries. In many instances, of course, certain types of small-scale fisheries may be the most efficient means of harvesting and bringing to the market various specialty products, particularly where the resource is fragmented and large-scale harvesting is precluded. Development assistance for these operations should, therefore, be an important component of long-range policies.

It is sometimes argued that the problems of small-scale fisheries should be dealt with in the context of general welfare policies rather than from the fisheries "sectorial" viewpoint. Even if other channels provide finance for small-scale fisheries operations, an understanding of the problems of these operations and the drafting of policy recommendations for economic relief and improvements of standards ofliving require an appraisal from a fisheries point of view. In many countries and for many groups of small-scale fishermen social objectives related to employment and producer living standards are likely to be of greater importance than economic objectives related to their contribution to the market economy. Variations between countries are therefore likely to be substantial in respect to development policies for such groups. Furthermore, it is common to find that different government organizations are charged with varying functions in this sector, and are probably working independently. Regardless of whether the economy is centrally planned or not it is imperative that there be coordination between the authorities responsible for the various aspects of small-scale fisheries development, and between the international agencies and national programs, if the sector is to derive lasting benefit from development efforts.

A common aspect of past and of some present development schemes for small-scale fisheries is the lack of long-term planning. Initial results of certain short-range schemes have been spectacular, but their long-term effects have frequently been negative and in a number of cases have created greater difficulties for future development. An integrated approach to the economic, social, and cultural aspects has been usually neglected: technological, institutional, and infrastructural changes have been made which in themselves may have been successful, but did not create the expected overall uplift of the sector.

For example, in one fish culture development, it was found that farmers would not crop their ponds because they retained the "cattle complex" whereby a man is considered rich if he has great numbers of animals. In consequence the fish became stunted due to over-stocking and they were too small to find buyers in the local market. In another case the introduction of fish-smoking ovens in a marginally poor firewood area resulted in denudation of the local forest and the eventual disuse of the ovens due to the high cost of firewood. The introduction of diesel engines and small winches on fishing boats that previously used sail and oars resulted in a crew reduction from 14 to 6, but created much unemployment until a local refinery was persuaded to engage ex-fishermen as laborers on a priority basis. The often-repeated failure of long-term benefits from outboard mechanization schemes derives from the neglect of the need for training repairmen and making spare parts available locally.

Objectives

DEVELOPED COUNTRIES

The introduction of assistance to small-scale fisheries in developed countries is usually of recent origin. National fishing industries were built up prior to the second world war by vessel owners and other entrepreneurs, without any assistance from governments or other institutions. It was not until after this war that the industry as a whole felt the cumulative effects of lowered productivity of fishing grounds, a lack of available capital to replace damaged or inefficient vessels, an increase in production costs, and a reduction of demand for fish as other commodities became more readily available again. The need for re-equipment of fishing fleets to lower production costs then became painfully evident, but few enterprises had sufficient financial resources and the need for capital had to be met from outside the industry.

To a greater or less extent these factors have influenced the development of fishery policies in western Europe, North America and a number of developed countries elsewhere. Individual circumstances have varied and different factors do not apply equally to all countries, nor in the same degree to all sectors of the fishing industry within a single country.

To deal with the situation governments devised new policies aimed at (a) improving the efficiency of production and distribution and reducing costs in order to increase incomes and profitability, and (b) maintaining the contribution of fisheries to national food supplies and the export trade, and increasing the attractiveness of fishery products for domestic and overseas consumers.

There are, however, other special objectives in developed countries which cannot be applied generally, for example, aid for the relief of distress caused by natural disasters such as typhoons (Japan), or hurricanes (USA). Alleviation of economic distress is common in the small-scale fisheries of Japan and the United States, and is done chiefly by means of re-equipment, although such measures have been introduced mainly for politico-economic and social reasons. A third objective (again of a socio-political character) is directed toward the improvement of social conditions in an area in order to improve its fishing potential. South Africa is an example of this sort, where large and prolific fishing grounds had remained unexploited because of lack of shore facilities. Housing, public utilities, and processing plants were provided and helped to increase the production of fish, especially pilchards.

Another objective in developed countries is the provision of ancillary services for fishery industries: roads, harbors, bait depots, and so on. All these services are required by small-scale fisheries in both developed and developing countries.

To sum up, in developed countries action for developing the small-scale fisheries is formulated with regard to special difficulties arising largely as a result of natural, biological, and political factors outside the control of the entrepreneurs. To overcome these difficulties it is necessary to re-equip the catching, processing, and distributive parts of the industry; to improve efficiency and reduce costs by providing financial assistance from sources outside the industry.

Success in achieving objectives lies in basic agreement between government and industry on objectives and on methods of their attainment. Failure to obtain agreement will lead to disaster since in a private enterprise economy the industry is free to choose whether or not to use the facilities created.

DEVELOPING COUNTRIES

The contrast between developed and developing countries is characterized by the late stage of economic development in the former when measures were adopted to meet a sudden and temporary worsening of the economic position of fisheries, compared with the planned policies in developing countries.

The problem for most of the developing countries is the need to increase fish production, especially at the small-scale level and to meet the needs of the rapidly increasing population. This demand calls for improvements in methods of production, marketing, transport, and distribution.

The obstacles impeding development are formidable. There is a general lack of biological and economic data; the fishery is predominantly a small-scale one; and few studies have been made on the biological, economic, and social effects of increased exploitation. Problems associated with catching, handling, and marketing larger quantities of fish are also poorly understood.

The fishing vessels, methods, and fishing gear are usually unsophisticated, requiring much labor. In a majority of cases the vessels are unsuitable for mechanization, but where mechanization is possible the increase in productivity has been very marked.

Fishing is by tradition a low-class activity in most of these countries, and the fishermen are often ridden by superstition and prejudices. The lack of training and technical knowledge demands a time-consuming training and education program.

A further problem of small-scale fisheries in developing countries is the inadequate and primitive marketing and distribution methods. Marketing is often in the hands of quasi-monopolistic middlemen who, while performing an economic function, are usually held to conduct it to the disadvantage of the fishermen. Policy measures to improve the marketing system and to widen the credit facilities available to fishermen have to face the problem of dealing with the middlemen. Merely to make government loans available to fishermen is apt to be useless because of the middlemen's control over other ancillary services, which makes it inexpedient or impossible for fishermen to disregard the credit they offer. Objectives in marketing must, therefore, be broadly based on the provision of alternative facilities of all kinds, such as cooperative societies or direct services by government agencies.

In meeting these needs and objectives the greatest difficulty facing the governments concerned is the lack of capital. There are strong competing demands from other sectors of the economy, many of which, whether ancillary to fishery development or not, have equal or greater priority in national development plans. The main reason for the lack of capital in developing countries is the very low per capita income of its population. As a result the rate of saving is too low to permit capital accumulation at anything like the rate needed for economic development. An objective of governments in developing countries must therefore be the stimulation of growth in those sectors of the economy where prospects for "self-sustained" growth appear greatest. The fisheries sector is considered to be one where capital investment can help achieve this objective because: (a) with the introduction of new fishing equipment and emphasis on technical training, the range of fishing operations can be extended beyond coastal or local waters and more productive grounds exploited; and (b) with improved facilities in the marketing sector, costs of distribution can be lowered and consumption expanded.

To sum up, the objectives in developing countries are wider in scope than those in developed countries. The objectives are similar in that both aim to increase productivity and to reduce the cost of operations in all sectors of the industry. The scope of improvement possible is, however, much greater in developing countries because of the possibility of exploiting new fishery resources through employment of improved equipment and techniques.

Social and political objectives are particularly significant. The need is not merely to safeguard the social and economic welfare of the fishing communities as in developed countries, but to increase earnings and improve the standard of living of fishermen well above their present low levels; and also to raise the nutritional level of the whole community by making available increased supplies of animal protein. During the first phase of any scheme, efforts will have to be made to rid the fishermen of oppressive burdens of debt incurred under present marketing and financing arrangements.

General objectives of national economic growth have great significance for the fisheries sector, for example, provision of roads, transport, housing, landing and harbor facilities, cold storage and markets. In a number of developing countries these developments are critical to the development of the small-scale fisheries.

Methods

The methods employed in developing small-scale fisheries are quite varied in different countries. This is because of differences in immediate objectives and in stages of development, because of the variety of their social and economic organization, and also simply for historical reasons.

In a majority of countries methods are conceived to achieve specific rather than general objectives, but almost always with a view to securing balanced progress. This may require curtailment of development of some sectors in order to ensure coordination. For example, the introduction of a new type of inshore vessel may need to be delayed until evaluation of the results of trial fishing with the prototype has been completed, and possible problems concerned with the landing, handling, and storage of the larger catches have been assessed.

Methods also depend on the amount of funds available. Broadly speaking, the small-scale sector is allocated too little money to permit general assistance, so those most in need have to be carefully selected. Policy decisions must be made early in any improvement scheme, since the methods employed must be effective enough to ensure that fishermen carry out the improvements, and that comprehensive and integrated development of the sector is possible within the financial limitations.

Funds are usually in the form of loans, grants, subsidies, taxation, and import duty relief, guarantees and loan insurance, hire-purchase and credit sales.

The aid available, no matter in what form, must be sufficient to encourage fishermen to carry out the development objectives but not so large that needs are too generously covered and in consequence an inadequate number of projects are carried out. The opposite danger of spreading funds too thinly leads to the danger of discouraging the sector from carrying out the desired developments. In developing countries it may be prudent to keep loans small, even if it means choosing small-scale objectives, because of the inability of fishermen to handle large sums.

The support of the fisheries sector must be sought for the objectives and methods in a private enterprise economy. Schemes which are inadequate or badly formulated will fail financially. This consideration does not apply so strongly in a partially planned economy.

Since objectives are frequently formulated prior to deciding on the methods to be used, it is necessary to take stock of the existing situation and examine the many facets of the small-scale sector once the objectives have been formulated. Whilst the majority of developed countries, through their long fishery history, have much of the data readily available, this is not so in the majority of developing countries. In consequence, and more particularly in view of their many experiences with "piecemeal" methods which have had little lasting effect, the multi-disciplinary integrated approach is now regarded as the most suitable for developing countries.

DEVELOPED COUNTRIES

In examining the types of methods used by developed countries to stimulate development of their small-scale fisheries, one must take into consideration the attitudes generally adopted to the whole fishery sector. It is common to find that the assistance given is aimed at specific rather than general objectives and that government policies are based strictly on need and are considered as temporary expedients. The administration has to strike a balance between the interests of the economy as a whole, in keeping special assistance as limited in nature and extent as possible, and the need of the industry to have some minimum guaranteed amount and period of aid so that it may proceed to re-equip or reorganize with confidence.

Unfortunately the application of this basic philosophy can be hampered by various factors. For example, the rapid technological changes in fish-finding equipment and the need to exploit more distant waters result in rapid obsolescence of vessels and expensive fleet replacements at rather short intervals. Another factor is the tendency of those receiving assistance to consider it as a permanent factor in their operations, and it is becoming evident that with present economic trends in the major fisheries assistance may need to be reorganized as a semipermanent rather than a temporary feature.

Assistance to the small-scale sector in most developed countries has already assumed a more or less permanent nature, since it is unlikely that social and economic conditions in this sector will undergo a dramatic change. For example, in most western European countries, notably the United Kingdom and West Germany, aid for the inshore and coastal fishermen began shortly after the end of the recent world war and is still continuing. The aid is chiefly in the form of loans, not infrequently limited to encouraging cooperative society development by supplying the aid through the societies rather than to individual fishermen. The considerations are chiefly social, since the costs of transfer of new industries to remote coastal areas, or the alternative of massive coastal depopulation, are generally held to be financially unacceptable, so the aim is to give fishing communities a better standard of living. Cuba, however, has recently taken steps to bring industry and utilities to coastal fishing villages in order to stem the drift to the towns.

In France, for example, fishermen have access to aid funds through eight schemes[2]: interest rebates to build vessels; loans for building and equipping vessels; loans from cooperative organizations, especially to small-scale fisheries for vessel building and modernization; subsidies to build vessels; subsidies especially for small-scale general fisheries development; subsidies to regional funds for organization of markets; subsidies for organization of the sardine market; subsidies for the organization of frozen fish markets.

These methods of providing help are designed to meet the objectives of boat and equipment modernization, development of cooperatives, and organization of markets especially for sardines and frozen fish.

DEVELOPING COUNTRIES

As mentioned earlier, the problem in devising methodology for encouragement of the small-scale fisheries in the developing countries is often that there is a lack of data on the existing fishery, its resources, operations, organization, and financial position. While in the past "piecemeal" schemes have been introduced to develop certain aspects of this sector, e.g. mechanization, new fishing gear and so on, the provision of background data is an essential pre-requisite to ensure a balanced multidisciplinary approach to development.

The collection of these data should ideally be devised to cover the following:

Fishery resources — the compiling of information on the present species caught, and whether the stocks are fully utilized or offer scope for greater utilization; assembly of data on catches broken down by species, fishing area, weight, year-class and seasonal indications of availability. In countries having extensive freshwater areas an assessment of the feasibility of establishment of fish-farming and hatcheries using existing or introduced exotic species also needs to be made.

Existing fisheries — the location of fishing centers, the number of fishermen involved, the numbers and types of fishing vessels in use, the types of fishing gear used, the types of fish caught by mechanized and unmechanized vessels, the harbor and shore facilities for fish handling and processing, the pattern of ownership and the credit structure. Special attention should be given to assessing the capability of the infra-structure to deal with any increase in fish landings.

Fish marketing — the organization of distribution channels, location of market centers, their capacities and potential; preferences of consumers and amounts they are able to pay for fish; statistics on existing products not only by type of product but also by area and ethnic group. An assessment should also be made of the possibilities for expanding fish sales outlets (e.g. to schools, military establishments, plantations, etc.) and for mounting "eat more fish" campaigns. If the sector has export products, or the objectives require the development of export sales, then data must be collected on the most suitable products for export, the capability of the industry to organize export marketing operations, the economic factors affecting the industry's position in overseas markets, the reliability of and need for better statistical data collection on exports/imports, production costs, prices and opportunities in overseas markets.

Analysis of the above data will normally indicate whether the objectives are realistic or whether they need to be recast, and will provide information for decisions on: suitable locations, mode of fishing operations, vessels to be introduced over a planned period, any requirements for development of harbor and shore-based facilities, processing and product development, marketing programs, training schemes, foreign staff requirements, sources of financing and credit, organization and administration, cost estimates and prediction on investment return.

The need for further studies or research in specific areas will also emerge, but this should neither delay the development of the methodology nor the start of a phased program of implementation, initially with pilot-scale operations. The aim of the pilot operations is to show the viability of a commercial fishery. A typical approach would perhaps have the following pattern for some developing countries:

Pre-project activities
- recruitment of Team Leader
- location and establishment of headquarters and workshop
- recruitment of staff/consultants
- preparation of detailed work plan
- purchase of equipment

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[2] OECD 1971. Financial support to the fishing industry.

Initial phase — improvement of production
- mechanization or remechanization of suitable vessels
- introduction by demonstration after test fishing of new and improved fishing gear and techniques
- highly practical training of fishermen in engine, vessel, and fishing gear maintenance and operation
- creation of group purchase facilities for fishing equipment
- stimulation of group activities and training in cooperative principles; training of government extension staff/counterparts.

As production improves, the need for other methods for development arises:

Secondary phase — improved processing
- continuation of mechanization and training
- testing and then introduction of new and improved fish processing methods (e.g. drying, smoking, salting, etc.)
- extension of training in these methods whilst building improved smoke houses, stores and introducing packaging materials

Tertiary phase — improvement of marketing and development of cooperatives
- combine phases 1 and 2 activities
- strengthen existing marketing methods
- introduce improved methods of sorting and handling, transport, storage, etc.
- develop the cooperative structure within any existing cooperative union and train government counterpart officers in collaboration with any existing Cooperative Department

Final phase — establishment of formal cooperatives

Cooperatives must be planned to meet actual requirements and local experience and development. At an early date they should take over responsibility for members' repayment of loans, marketing of catches, sales of fuel and oil, fishing gear, and repair and maintenance facilities.

It should be emphasized that no one set of methods can be rigidly applied to all circumstances. Each country must decide for itself, having due regard to socio-economic and political circumstances, which methods are likely to be the most suitable for its own particular situation.

In this connection, one East African country requested FAO consultant advice on methods for development of its fisheries. After a thorough study, the consultant recommended not the development of the fishery itself but the building of feeder roads as the main method of development. His advice was followed and these roads were constructed together with simple market stands for fish retailers at road heads. These developments triggered a rapid development, not only of the fishing operations but also of fish distribution and sales in many remote areas. Additional benefit was gained by the agricultural sector, since cultivators moved in along the roadsides and grew cash crops which provided an extra source of business for the fish-transport trucks serving the fishing villages.

Conclusion

As mentioned earlier, there are wide differences in policies for development of small-scale fisheries. Additionally, due to the present state of information on development objectives and methods, their successes and failures, it is not possible to present a comprehensive review leading to conclusions on the recommended practices for given fisheries situations.

The few examples given serve to illustrate how governments have endeavored to meet the needs of the small-scale sector and to adapt their different measures of assistance to the hazards and fluctuations inherent in the fishing industry, whilst maintaining effective administrative control consistent with the public interest.

It is hoped that this paper will illustrate the complexities and difficulties of the development problems in this sector and endorse the need for a more comprehensive exchange of information and views among participants in this meeting. There is a need for assembling such information, based on practical experience, to accelerate the development of these fisheries.

Prospects of the Utilization of Krill and Other Nonconventional Resources of the World Ocean[1]

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When animals of lower trophic levels are consumed by pelagic fishes, only 1–3% of the energy they contain is transformed into the new kinds of living matter which constitute useful fishery production. Thus the animals in the lower trophic levels, being more "economically profitable" and in much greater abundance, offer strong possibilities for increasing commercial utilization of ocean resources. The most urgent task is to develop commercial fisheries among animals at the second trophic level, the zooplankton. The most promising of these are the crustaceans, especially the krill of the antarctic, *Euphausia superba*, which occupy areas of the ocean south of the antarctic convergence, in extremely high concentrations. The resource may be between 0.8 and 5 milliards of tons, yielding a total commercial catch as high as 25–50 million metric tons.

Other crustaceans that may some day support commercial fisheries include other species of *Euphausia*, *Munida*, *Pleuroncodes*, and *Calanus*.

The problems facing the development of fisheries for these animals are to devise efficient catching methods and methods of processing that preserve the nutrient value while providing acceptable products. Soviet work with krill has yielded promising results. A special midwater trawl has given catches of 10–20 tons/hr. The food value of krill is high. It can be made into protein paste for human consumption, or used as fodder. To make the paste the krill are pressed, the extracted juices treated with heat, and the coagulated paste is separated and frozen. Tests with animals fed this paste showed higher rates of growth than those fed with beef. Krill has been used in the production of "shrimp butter" and "melted cheese," the latter having been produced commercially since 1970. Other products show promise.

Certain squids may become of great importance commercially, although some may be useful only as fodder because of their chemical composition. Some fish species at the third trophic level have dense stocks and offer promise. Among these are fish of the families Carangidae and Stomateidae. These may be used to produce edible fish powder. They can best be caught with fast pelagic trawls. Planktophagous bathypelagic species are often numerous at depths to 500–600 m, especially some myctophids and bathylagids. Associated with the antarctic krill are krill-eating fishes of the family Nototheniidae, of high food value and great abundance.

To develop these resources specially designed vessels and improved hydroacoustic equipment are required, as well as automatically controlled fishing gear and submersibles to study fish behavior.

Une proportion de 1 à 3% seulement de l'énergie consumée par les organismes vivant au niveau trophique inférieur contribue à l'accroissement du poids du corps et est transformée en de nouvelles formes de vie qui constituent un potentiel de production halieutique intéressant. Ainsi, les animaux des niveaux trophiques les plus bas, qui sont plus rentables économiquement et beaucoup plus abondants offrent de grandes possibilités d'accroître l'utilisation commerciale des ressources océaniques. La tâche la plus urgente est de développer les pêcheries commerciales des organismes du deuxième niveau trophique, le zooplancton. Les plus prometteurs sont les crustacés, en particulier le krill de l'Antartique, l'*Euphausia superba*. Il occupe certaines zones de l'océan austral, au sud de la zone de convergence antarctique, en concentrations extrêmement fortes. Les ressources pourraient se situer entre 0.8 et 5 milliards de tonnes, ce qui donnerait un rendement total des prises commerciales allant de 25 à 50 millions de tonnes.

D'autres crustacés pourraient aussi dans l'avenir contribuer aux pêches commerciales: autres espèces d'*Euphausia*, *Munida*, *Pleuroncodes* et *Calanus*, notamment.

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Il s'agit pour développer ce genre de pêche de mettre au point des méthodes de prises efficaces et des moyens de traitement qui conservent la valeur nutritive tout en présentant des produits acceptables. Les travaux menés en Union soviétique sur le krill ont donné des résultats prometteurs. En utilisant un chalut pélagique spécial on a obtenu des captures de 10 à 20 tonnes par heure. Le krill a une haute valeur nutritive et il peut être transformé en pâte de protéines pour l'alimentation humaine et en produits d'alimentation animale. Le procédé consiste à presser le krill, à traiter le jus extrait à la chaleur après quoi la pâte coagulée est séparée et congelée. A l'essai, les animaux nourris de cette pâte ont montré des taux d'accroissement plus élevés que ceux qui étaient nourris avec du boeuf. Le krill a été utilisé dans la production de "beurre de crevettes" et de "fromage fondu," ce dernier étant produit commercialement depuis 1970. D'autres produits encore paraissent intéressants.

Quelques encornets auraient une grande importance commerciale. Mais, en raison de leur composition, certains d'entre eux sont seulement utilisables comme produits d'alimentation animale. Certaines espèces de poisson du troisième niveau trophique existent en stocks denses et offrent de bonnes perspectives. A citer parmi ces poissons les familles Carangidae et Stomateidae. Ils peuvent être utilisés pour produire de la farine de poisson comestible. Le meilleur engin pour les capturer est le chalut pélagique rapide. Les espèces planctophages bathypélagiques sont souvent nombreuses à des profondeurs allant de 500 à 600 m, en particulier certains myctophides et bathylagides. On trouve, associés au krill antarctique les poissons krillophages de la famille des Nototheniidae très abondants et d'une haute valeur nutritive.

Pour exploiter ces ressources, il faut des bateaux spécialement conçus et du matériel hydroacoustique perfectionné, ainsi que des engins de pêche automatiques, et des submersibles pour etudier le comportement du poisson.

Sólo del 1 al 3% de la energía consumida por los animales del nivel trófico más bajo se traduce en un aumento del peso corporal y se transforma en nuevos tipos de materia viva, que constituyen una producción pesquera útil. Así pues, los animales de los niveles tróficos más bajos, que son más "rentables económicamente" y existen en mucha mayor abundancia, ofrecen grandes posibilidades de incrementar el aprovechamiento comercial de los recursos oceánicos. Lo más urgente es crear la pesca industrial de los animales del segundo nivel trófico: el zooplancton. Los más prometedores de éstos son los crustáceos, especialmente el krill del Antártico (*Euphausia superba*), que se encuentra en algunas zonas del sur del Pacifico, al sur de la convergencia antártica, en concentraciones de gran densidad. Tal vez estos recursos sean del orden de 800–5000 millones de toneladas, con una captura comercial total que puede llegar a cifras tan altas como 25 o 50 millones de toneladas métricas.

Entre otros crustáceos que pueden llegal algún día a sostener pesquerías comerciales, están especies de *Euphausia*, *Munida*, *Pleuroncodes* y *Calanus*.

El principal problema que plantea la pesca de estos animales es la preparación de métodos eficientes de captura y de métodos de elaboración que conserven su valor nutritivo, presentando, al mismo tiempo, productos aceptables. Los trabajos soviéticos con el krill han dado resultados prometedores. Con una red especial de arrastre entre dos aguas se han logrado capturas de 10–20 toneladas por hora. El valor alimenticio del krill es muy elevado, y los crustáceos capturados pueden transformarse en pasta de proteínas de pescado y en piensos. Para preparar la pasta, se prensa el krill, se tratan térmicamente los jugos extraídos y se separa y congela la pasta coagulada. En los animales alimentados con esta pasta se han registrado índices de crecimiento mayores que en los alimentados con carne de vacunos. El krill se ha utilizado para producir "mantequilla de camarón" y queso fundido, producto éste último que se viene produciendo comercialmente desde 1970. También otros productos parecen prometedores.

Tal vez también algunos calamaresa tengan gran importancia comercial, aunque es posible que algunos de ellos sólo sean útiles para piensos, debido a su composición. Algunas especies de peces del tercer nivel trófico se presentan en poblaciones de gran densidad y ofrecen buenas promesas. Entre ellas pueden citarse las familias Carangidae y Stomateidae, que pueden utilizarse para producir harina de pescado comestible. El arte más eficaz es la red de arrastre pelágico. Las especies batipelágicas planctófagas, especialmente algunos mictófidos y batilágidos, abundan con frecuencia a profundidades de 500–600 m. En asociación con el krill del Antártico se encuentran peces consumidores de krill de la familia Nototheniidae, de gran valor nutritivo y muy abundantes.

Para explotar estos recursos se requieren embarcaciones de formas especiales y mejor equipo hidroacústico. Es necesario, además, emplear sumergibles para estudiar el comportamiento de los peces y utilizar artes de pesca controlados automáticamente.

Oceanic Production

THE assessment of the biological resources of the world ocean and the development of trends and methods of their rational utilization is a most important and urgent problem facing many countries engaged in fishing for marine species. Most scientists believe that the world catch of fish and marine invertebrates can be brought up to 80–100 million tons (Finn 1964; Kask 1963; Moiseev 1964, 1969; Bogorov 1965, 1967); however, there is a limit to an increase in the production of modern fisheries, which is primarily determined by the limited level of fish resources in the ocean.

The trophic structure of oceanic communities is so arranged that at each higher trophic level most of the assimilated energy of the lower level is dissipated in metabolic processes, which results in a considerable loss in the yield of useful production, by not less than an order of magnitude.

The food consumed by pelagic fishes is known to be mainly used in metabolic processes (97–99%). Only a minor part of the energy ingested from the previous trophic level (1–3%) goes into an increase of their body weight and so is transformed into new living matter that constitutes useful fishery production (Steele 1964; Lasker 1966). It should be noted that these data apply only to adult pelagic fish. In young fish food energy spent on increasing their weight amounts to 50–60%, and in adult demersal fish it is up to 10–15%. Nevertheless, it is clear that higher trophic level species are the least "economically profitable" from the viewpoint of their utilization by fisheries. In this respect a search for objects of potential fisheries among marine organisms at lower trophic levels and of much higher abundance than fish offers excellent possibilities for increasing the commercial utilization of the biological resources of the world ocean.

It is our belief that the most urgent task is to find objects of potential commercial fisheries among marine organisms of the second trophic level, zooplankton.

A number of groups of zooplankton organisms, such as salps, ctenophores, siphonophores, medusae, Chaetognatha, etc., are not likely to be of great interest because their chemical composition is poor in substances of high food value. Apart from this, most of them are predators that feed on zooplankton rather than on phytoplankton, which sets a limit to their possible biomass and, consequently, their possibilities for commercial utilization.

Antarctic Krill

Crustaceans form the most promising group of planktonic organisms. This group is characterized by extremely high biomass. In different geographic zones of the ocean, crustaceans make up from 50–95% of the total zooplankton production. The bodies of these animals contain great amounts of proteins, fats, and carbohydrates readily assimilated by the human organism, as well as valuable vitamins and trace elements that are required in the normal human diet and are indispensable in dietetic therapy.

Among the variety of planktonic crustaceans the species dominant in biomass is *Euphausia superba* Dana (family Euphausiidae). Massive concentrations of this species are known as the antarctic krill.

Euphausia superba is one of the most typical representatives of the antarctic macrozooplankton that inhabits the ocean south of the antarctic convergence. In certain areas of the southern ocean dense concentrations of *E. superba* are formed, whose biomass considerably exceeds that of the mesoplankton. While the maximum biomass of mesoplankton in places of its highest concentration is 20–30 g/m^3 (even 1 g/m^3 is a high figure for mesozooplankton), the biomass of the antarctic krill can be as high as 10–15 kg/m^3 (Makarov and Shevtsov 1971).

The formation of concentrations of *Euphausia superba* is determined by a number of factors, both biotic and abiotic. It was found that highest concentrations of this crustacean are observed during the spring, summer, and early autumn (November–April), and are associated with reproduction and feeding (Naumov 1963; Makarov and Shevtsov 1969, 1971).

Soviet studies over many years on the distribution of antarctic krill in the Scotia Sea suggest that the formation of concentrations in the surface layer or in midwater is governed mainly by the nature of the water dynamics. Analysis of the vertical water circulation in areas of massive krill concentrations shows that swarms are associated with areas of convergence or "downwelling" adjacent to upwelling zones. The downwelling areas where krill concentrations are located may occur either within the central part of the anticyclonic circulation, or at the peripheral part of the cyclonic circulation, or they may be associated with rectilinear motion along the coast or along a submerged elevation, but they invariably occur to the left of the horizontal direction of flow. An important condition for the formation of krill concentrations is that the downwelling areas should be surrounded by peculiar "walls" of a dynamic (in the open ocean) or orographic (in coastal areas) nature (Elizarov 1971).

Oceanic Conditions for Krill Concentrations

The conditions that govern the formation of massive krill concentrations in the Scotia Sea are of great theoretical and practical importance because the types of vertical circulation described above may be found in many areas of the southern ocean. It follows that krill concentrations may be located in the open part of the ocean — in frontal zones, in gyres that develop along the margins of horizontal currents, and in waters adjacent to islands and submerged elevations to the left of the horizontal flow running along the coast. Particular attention should be given to the frontal zone of the antarctic convergence, to cyclonic and anticyclonic gyres in the Ross, Amundsen, and Bellingshausen Seas, and to coastal waters on the lee side of the antarctic islands and banks (South Georgia, Bouvet, Kerguelen, Balleny, Scott, and Peter I Islands; the Ob, Lena, and certain other banks). Massive concentrations of antarctic krill have already been observed in many of these areas.

According to estimates made by different investigators, based on data on the food of baleen whales (McQuillan 1962; Perquegnath 1958) and other krill consumers (Klumov 1961), the total resource of antarctic krill in the southern ocean amounts to the astronomical figure of 0.8 to 5 milliards of tons. It is not possible at this time to give a precise figure, but those referred to above are an indication of the very high level of the biomass of this species.

Great abundance and the formation of massive concentrations in a number of areas of the vast southern ocean indicate excellent possibilities for commercial utilization of krill resources, as the object of a specialized fishery.

Other Crustaceans

Considering that in the krill population commercial sizes are not likely to make up more than 30–40% of the total resource and that a considerable part of the production is consumed by a great variety of animals, the total potential commercial catch of antarctic krill may be expected to be not less than 25–50 million metric tons.

Among planktonic crustaceans there does not seem to be any other species comparable to antarctic krill in abundance and in the extent of distribution. Nevertheless, in the not too distant future certain species may come under the scrutiny of fishery science and then of the fishing industry. Outstanding among these are a number of euphausiids of the southern and northern hemispheres, such as *Euphausia vallentini*, *E. cristallorhophias*, *Thysanoessa macrura*, *T. vicina*, *T. inermis*, and *T. rachii*, as well as the galatheid crabs that form massive concentrations, e.g. *Munida gregaria*, *M. subrugosa*, *Pleuroncodes planipes*, and *P. monodon*.

Pleuroncodes planipes and *Munida gregaria* form massive pelagic concentrations of young animals in the waters of the Californian Current and in the Falkland–Patagonia area, respectively. *Pleuroncodes monodon* and *Munida subrugosa* concentrate in the near-bottom layer in some areas of the South American continental shelf. The annual catch of these crustaceans in Chilean waters amounts to 10,000 tons. The population of *Pleuroncodes planipes* has so far remained virtually untouched by exploitation. According to an estimate by Longhurst (1968), commercial exploitation of the above mentioned galatheid species may yield 30,000–300,000 tons annually. It should be mentioned that Longhurst believes benthic concentrations of Galatheidae to be more promising for exploitation than pelagic concentrations.

In the waters of the northern hemisphere concentrations of "red calanus" (*Calanus finmarchicus*) are well-known, as well as other copepods. However, because of the peculiarities of the distribution of these crustaceans, their relatively small size, and the fragility of the chitinous carapace, the main problems for commercial utilization would be to devise methods of catching and processing them. It would be necessary to catch these animals in commercial quantities without destroying their carapaces, so as not to lose the most valuable part of the product; and it would be important to apply a processing method that would give a food product value not only in respect to chemical composition but also in palatability and appearance.

Composition and Processing of Krill

Early experimental catches of antarctic krill by Soviet scientists in the Scotia Sea, and experiments on processing krill to obtain food and fodder, have yielded promising results and proved the possibility of the commercial utilization of this resource.

Krill concentrations were fished with a special midwater trawl and catches amounted to 10–12 tons/hr.

Processing studies have shown that krill will yield considerable amounts of animal protein. As in all other crustaceans, the protein of the antarctic krill contains amino acids indispensable for man, high amounts of trace elements, and group "B" vitamins. Krill oil contains indispensable fatty acids such as arachidonic, linoleic, and linolenic acids. The total chemical composition of raw krill is characterized by the following percentages: moisture, 72–84%; protein, 13–18%; fat, 2–6%; ash 2–3%.

The krill processing technology worked out by VNIRO makes it possible to obtain food protein paste and fodder meal at rates of 25–35% and 8–10%, respectively, of the raw krill input. When krill is reduced directly to meal the output is 21–24% depending on the size composition of the animals.

The method of preparing the protein paste consists of pressing the krill, heat treatment of the extracted juice, and separation of the thick coagulated paste, which is red in color. The paste is then packed in trays and frozen at –18C. The storage time of this product is up to a year. The composition of the paste is characterized by the following percentages: moisture, 70–75%; protein, 13–20%; fat 3–10%; carbohydrates, 1–2%; ash, 1.5–3%. Krill paste has been shown to have a high content of macro- and microelements such as potassium, iron, manganese, zinc, cobalt, iodine, etc. The amino-acid composition of the protein paste (as a percentage of its protein) is noted for great variety:

lysin	7.7	alanine	4.9
histidine	2.1	cystine	1.1
arginine	6.0	valine	6.8
aspartic acid	10.9	methionine	1.7
threonine	4.7	isoleucine	7.6
serine	3.5	leucine	9.6
glutamic acid	10.5	tyrosine	4.4
proline	4.4	phenylalamine	5.3
glycine	44.0		

To determine the nutritive value of the paste the Kiev Research Institute for Food Hygiene conducted biological studies with animals. It was found that animals receiving krill paste as a protein component of their diet showed a higher rate of increase in weight than those receiving beef. Histological analyses of internal organs in experimental animals did not reveal any pathologic changes. Blood tests also confirmed the favorable effect of the krill paste: the hemoglobin content and the phagocytic activity were higher in the experimental than in control animals.

Experimental introduction of krill paste into the diet of patients undergoing dietary therapy indicated a favorable effect of the paste in treating common diseases such as hyperacid ulcer of the stomach and atherosclerosis. For example, the healing effect of the paste on ulcers of the stomach was reflected in a 60% increase in the number of patients cured by therapeutic means without recourse to surgery.

Food Products from Krill

Numerous experimental studies were conducted in an endeavor to find the best ways to use the krill paste. It was found to go well with butter and cheese. Recipes were formulated for "shrimp butter" and melted cheese, which was labeled "Coral" and has been produced commercially since 1970.

The prospects for using krill paste in sausages also appears to be good.

Many ready-to-eat products using krill paste have gained wide recognition, e.g. salads, stuffed eggs, and stuffed fish.

High calorie fodder meal has been obtained from the California red crab *Pleuroncodes planipes*. The meal contains 5–6% moisture, 25–29% protein, 3–5% fat, and 64–67% ash.

These first attempts by Soviet scientists to utilize antarctic krill and other crustaceans are by no means the only possible way to use planktonic production. In the near future other means of catching and processing these animals are likely to be devised that may be no less effective and economical. Particularly promising are netless catching methods, using sucking and filtering devices similar to fish-pumps, and also the stimulation of artificial swarming by means of light, electric current, sound, and odors.

Cephalopods

Among other pelagic invertebrates certain nectonic cephalopods may become of great commercial importance. Reliable data on the sizes of the stocks of these animals are not available at present. However, the great abundance of foods that may be used by squids (zooplankton, young fish, small fish) suggests that in considering the problem of increasing production from the pelagic waters of the ocean this group should not be underrated.

Unfortunately, a part of the species of cephalopods that form the basis of the food of animals such as sperm whales and some predacious bathypelagic fishes, and that seem to be the most abundant species in this group, are not likely to be of great commercial importance. The bodies of these animals (deep-sea squids) contain over 90% water and a considerable admixture of ammonia compounds. Nevertheless, the fact that the biomass of these species is estimated at tens of millions of tons merits consideration of the possibilities of utilizing them for industrial purposes. Here again scientists are faced with a number of problems requiring comprehensive investigations. As regards epipelagic squids, which are universally recognized as a delicacy, the problem of commercial utilization rests on the inadequacy of modern gear for catching these fairly large and extremely active animals.

Underutilized Fishes of Temperate Waters

Among the ichthyofauna of the world ocean there are many species of the third trophic level, the stocks of which are distinguished for their high density, but for some reason are not exploited. These are species living mainly in the waters of the southern hemisphere, both in distant neritic areas and in the epi- and bathypelagic waters of the Atlantic, Indian, and Pacific oceans and in the antarctic waters. Species of families Carangidae, Stromateidae, Gadidae, Merluccidae, Myctophidae, Bathylagidae, Paralepidae, Nototheniidae, and Macruridae offer considerable promise as objects of commercial fisheries for human consumption and industrial purposes.

The great volume of flow of the Amazon, Orinoco, Paramaibo, and other rivers together with intensive upwelling associated with the divergence of the South Trade Drift makes for high productivity in the distant neritic zone off South America, which results in the formation of massive concentrations of small plankton-eating fish of families Carangidae and Stromateidae. Most numerous are *Chloroscombrus chrysurus* and species of the genera *Trachinotus* and *Peprilus*. These fish are not over 20 cm in length and 150–200 g in weight. Their pelagic concentrations can be found in the 50–100 m layer at distances of 50–300 miles from the coast of Brazil. Despite their high abundance these stocks are not exploited, which apparently can be attributed to poor nutritional quality associated with their small size, and also the great mobility of their schools, which makes them difficult to catch.

At the same time the experience gained through food processing studies in the Soviet Union shows that such small fish, characterized by tough flesh and heavily calcified skeleton, may be used successfully to produce edible fish flour or protein concentrate. The flour is used in powdered fish soups and is added to bread as an animal protein supplement. The composition of the fish protein concentrate is 4–5% moisture, 93% protein, 0.3% fat, and 2% ash. The flour has a faintly fishy flavor. Powdered soups based on fish flour with macaroni or vegetables added have a storage life of 12 months. The waste after processing is reduced to meal used in animal feeding.

Fishing for pelagic concentrations of these fast swimmers is best done with midwater trawls towed at speeds not less than 5–6 knots, or with fish-pumps fitted with devices to attract the fish into the suction zone.

The foregoing also applies to pelagic fishes of the families Carangidae and Stromateidae of the northern Indian and South Pacific oceans, the stocks of which are underexploited at present.

Subantarctic and antarctic epi- and bathypelagic waters hold great promise for commercial exploitation since stocks of many fish species remain virtually unused.

Antarctic Food Fishes

A characteristic feature of the oceanographic structure of the southern ocean is the existence of meridional water circulation, which is established in the zone of action of the Antarctic Circumpolar Current. The meridional circulation results in the formation, in the area between 40° and 70°S, of the frontal zones of the subantarctic divergence (40–42°S), the antarctic convergence (47–50°S), and the antarctic divergence (62–66°S). The persistence of these frontal zones in the southern ocean where either upwelling or sinking occurs produces a high content of nutrient elements and a high abundance of zooplankton, particularly the antarctic krill (south of the antarctic convergence), with resulting optimum conditions for the vertical distribution, reproduction, feeding, and development of the larval and juvenile stages of pelagic fishes inhabiting these waters. The region of the southern margin of the antarctic convergence is characterized by high concentrations of zooplankton all year round, rather than only during the period of the summer maximum, and by intensive production of plankton to depths of over 500 m. This results from the meridional transport of plankton from the south to the north and its continuous accumulation and descent with the sinking waters (Voronina 1971). As a consequence of the deep-water distribution and high biomass of zooplankton, planktophagous bathypelagic species are widely distributed at depths down to 500–600 m in the waters of the southern part of the antarctic convergence. The most numerous are myctophids of the genera *Electrona* and *Gymnoscopelus;* also abundant are *Bathylagus antarcticum* (family Bathylagidae), *Paralepis atlanticus prionosa* (family Paralepididae), and certain other species. Pelagic concentrations of these fish are observed in the 200–600-m layer. All the abovementioned bathypelagic species are 10–25 cm in length and up to 200 g in weight. Despite their small size, many bathypelagic fish are likely to find use in food industry, for their meat is very tender and contains much fat.

Directly associated with the antarctic krill, which is a key link in the ecosystem of the southern ocean, is the distribution and the formation of concentrations of epipelagic krill-eating fish in and to the north of the antarctic convergence.

Of greatest importance among these fish are the two most abundant species: the southern blue whiting (*Micromesistius australis*) of the family Gadidae and the antarctic sidestripe (*Pleuragramma antarcticum*) of the family Nototheniidae.

The southern blue whiting is a fairly large fish, up to 45–50 cm in length and 0.7–1.0 kg in weight. It forms pelagic concentrations in the southern Scotia Sea (50–100-m layer) and bottom concentrations at depths of 200–400 m in waters of the Falkland shelf. The species is widely distributed in the highly productive krill zone, and results in its high abundance. The food value of this fish is high because its liver contains large quantities of oil rich in vitamins A and D. The meat can be used for human consumption and for reduction into fish meal.

An even more widely distributed species is the circumpolar antarctic sidestripe, which lives close to the edge of the pack ice. It forms pelagic concentrations in the layer from the surface to 100 m in the krill concentration areas. This fish, which may be up to 30–35 cm long and weigh about 300 g, has tender fatty meat and can be used for human consumption.

Along with these prospects for commercial exploitation of the plankton- and krill-eating fishes, we should not neglect the possibilities of bathyal fishes of the families Merluccidae and Macruridae, as well as certain large predacious fishes living in antarctic bathypelagic waters, which have remained practically untouched by fishing. These fish belong to a higher trophic level and their resources are by no means as great as those of plankton-feeders; however, with proper management their stocks could be fished and the catches used for the production of high-quality delicacies. Among these valuable species are the antarctic toothfish (*Disostichus mawsoni*), the rough-scaled rat-tail (*Coelorhynchus fasciatus*), and the Magellan hake (*Macruronus magellanicus*).

Conclusion

Development of exploitation of the productive areas of the southern ocean will largely depend for its success on the proper organization of comprehensive fishery research, with the use of highly effective means of finding and capturing the fish.

The great expanse of the ocean area, severe hydrometeorological conditions, and the peculiar horizontal and vertical distribution of the fish require that ice-shielded vessels with long sea endurance be used for exploratory work. Improved hydroacoustic equipment must be developed, and submersibles must be used for studying fish behavior in the water column. For some situations it will be necessary to create fundamentally new types of automatically-controlled fishing gear, capable of sweeping large areas and equipped with devices to attract the animals into the area swept by the gear, as well as to devise reliable means of inducing schooling behavior.

Considering man's ever-increasing requirements for animal protein, along with improved searching and harvesting, attention should be given to development of new processing methods so as to obtain food products from fish that will become the objects of commercial utilization.

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The Role of Aquaculture in Fishery Development and Management[1]

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Although historically there have been different patterns of development of aquaculture, present-day interest is mainly directed toward the establishment of viable industries. Emphasis in the major aquaculture areas of the world continues to be on the cultivation of species that are within the reach of most consumers. Aquaculture is also practised for the improvement of natural stocks through artificial recruitment and transplantation or for the production of bait, sport, or ornamental fish. The different types of aquaculture include culture of fish and shrimps in ponds, tanks, cages, enclosures, raceways, and recirculating systems, and "bottom" and "hanging" methods of mollusc culture.

World production through aquaculture (excluding bait, sport, and ornamental fish and production through stocking of open waters) is over 5 million tons. This has an important role in the food and nutrition of many countries and is particularly significant in integrated rural development.

Aquaculture can contribute significantly to meeting the demand for animal proteins in developing countries and increase the production of luxury foods. It can also serve as an efficient convertor of low-grade fishery products to high quality fish. The employment potential is high and well-managed installations yield favorable returns on investment.

Besides contributing to relieve pressure on intensively exploited stocks, aquaculture enables the development of resources within national boundaries. There is considerable potential for stock improvement through artificial recruitment and transplantation in certain areas. Possible adverse effects of aquacultural development can be eliminated by the adoption of appropriate remedial measures.

Although a world-wide survey has not yet been undertaken, it is known that extensive areas are readily available for aquaculture in many developing countries. In 11 countries of Asia alone, about 22 million ha have been identified as potential areas for fish culture. Sites for other types of aquaculture are much more extensive. An increase of up to 10 times in production through aquaculture by the year 2000 has been predicted.

Some of the existing misconceptions about aquaculture have acted as constraints to the development of the industry. Due to the lack of adequate planning, financing, and shortage of trained personnel, the existing knowledge is not being fully utilized. Besides better research facilities to fill the gaps in our knowledge, there is an urgent need to evolve suitable development strategies in the framework of national fishery development plans, to achieve targets of production in different countries.

Dans le passé l'aquiculture a pris diverses formes, mais à l'heure actuelle l'intérêt s'oriente surtout vers la création d'industries viables. Dans les principales régions d'aquiculture on continue de faire une large place à l'exploitation d'espèces accessibles à la plupart des consommateurs. L'aquiculture est aussi pratiquée pour améliorer les stocks naturels au moyen d'un recrutement artificiel et de la transplantation ou pour élever des poissons d'appât, des poissons destinés à la pêche sportive ou ornementaux. Les différents types d'aquiculture comprennent lélevage de poissons et de crevettes en étangs, viviers, nasses, enclos, passes et systèmes de recyclage, ainsi que la culture de mollusques au fond et par suspension.

La production aquicole mondiale (non compris celle des poissons d'appât, de ceux qui sont destinés à la pêche sportive et des poissons ornementaux ainsi que la production par empoissonnement des eaux libres) dépasse 5 millions de tonnes. Elle joue un rôle important dans l'alimentation et la nutrition de nombreux pays et présente un intérêt particulier pour le développement rural intégré. L'aquiculture peut notablement contribuer à satisfaire la demande de protéines animales dans les pays en développement et accroître la production d'aliments fins. Elle peut également convertir en poisson fin des produits de la pêche de faible qualité. Le potentiel d'emploi y est élevé et les installations bien gérées ont une bonne rentabilité.

Outre qu'elle allège la pression sur les stocks intensivement exploités, l'aquiculture permet la mise en valeur des ressources à l'intérieur des pays même. Un potentiel considérable s'offre pour améliorer les stocks par le recrutement artificiel et la transplantation dans certaines zones. Les effets néfastes qu'aurait éventuelle-

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ment le développement de l'aquiculture peuvent être éliminés par des mesures appropriées.

Bien qu'on n'ait pas encore entrepris d'enquêtes à l'échelle mondiale, on sait que de vastes régions se prêteraient à l'aquiculture dans beaucoup de pays en développement. Dans 11 pays de la seule Asie, environ 22 millions d'hectares ont été reconnus comme propres à la pisciculture. Des superficies beaucoup plus vastes seraient favorables à d'autres types d'aquiculture. D'après certains la production de poisson pourrait être décuplée d'ici l'an 2000 grâce à l'aquiculture.

Certaines conceptions erronées de l'aquiculture ont nui au développement de cette industrie. Faute d'une planification et d'un financement adéquats et d'effectifs suffisants en personnel qualifié, les connaissances actuelles ne sont pas utilisées à plein. Outre les meilleurs moyens de recherche indispensables pour combler les lacunes dans ce domaine, il est d'urgence nécessaire de concevoir des stratégies de développement appropriées dans le cadre des plans nationaux de développement halieutique afin que les différents pays atteignent les objectifs de production fixés.

Aunque a lo largo de la historia el desarrollo de la acuicultura se ha ajustado a esquemas muy diversos, en la actualidad se tiende principalmente a establecer industrias viables. En las principales zonas acuícolas del mundo sigue insistiéndose en el cultivo de especies que están al alcance de la mayoría de los consumidores. Se practica la acuicultura para mejorar las poblaciones naturales, mediante reclutamiento artificial y trasplante, o para producir peces para cebo, pesca deportiva u ornato. Entre los diversos tipos de acuicultura puede citarse el cultivo de peces y camarones en estanques, depósitos, jaulas, recintos, canales y sistemas de agua recirculada, y los métodos de cultivo de moluscos sobre el fondo y cuerdas suspendidas.

La producción acuícola mundial (excluida la de peces para cebo, pesca deportiva y ornato y la producción que se logra mediante la repoblación de aguas libres) es superior a 5 millones de toneladas En muchos países representa una función importante desde el punto de vista nutritivo y es especialmente significativa desde el punto de vista del desarrollo rural integrado.

La acuicultura puede contribuir mucho a atender la demanda de proteínas animales en los países en desarrollo y a aumentar los productos alimenticios suntuarios. Puede servir también para transformar productos pesqueros de baja calidad en pescado de elevada calidad. El potencial de puestos de trabajo es grande y con instalaciones bien administradas se obtienen rendimientos favorables de las inversiones.

Aparte de aliviar la presión a que están sometidas las poblaciones intensamente explotadas, la acuicultura permite mejorar los recursos dentro de los límites nacionales. Existen considerables posibilidades de mejorar las poblaciones mediante reclutamiento artificial y trasplante a determinadas zonas. Los posibles efectos negativos de la acuicultura pueden eliminarse adoptando las medidas adecuadas.

Aunque no se ha realizado aún un estudio internacional, se sabe que en muchos países en desarrollo existen amplias zonas en las que podría practicarse el cultivo de pesces. En sólo 11 países de Asia se han identificado como posibles zonas para cultivo en estanques cerca de 22 millones de hectáres, y las zonas que reúnen condiciones para otros tipos de acuicultura son aún más extensos. Se ha previsto que para el año 2000 la producción podria llegar a decuplicarse gracias a la acuicultura.

Algunos de los malentendidos sobre la acuicultura han contribuido a frenar su desarrollo. Por falta de planificación y financiación adecuadas y a causa de la escasez de personal bien preparado, no se aprovechan plenamente los conocimientos ya existentes. Aparte de crear mejores instalaciones de investigación para colmar las lagunas de nuestros conocimientos, es urgentemente necesario preparar métodos adecuados de fomento dentro de los planes nacionales de desarrollo pesquero, con vistas a lograr los objectivos de producción en los diferentes países.

THE history of aquaculture shows that it originated and developed under different social and economic conditions in various parts of the world. In Asia and the Far East, particularly in China, where it appears to have the longest history, culture of fish in ponds was undertaken to assure a reliable supply of an essential item in the people's diet, an item which could be produced at a cost little more than the labor of the farmer and his family members. The harvest from open waters was either unavailable or inadequate, or very often distributed in a very poor state of preservation. Brackish-water farming developed in parts of India as a stage in land reclamation, which involved poldering and trapping of silt to raise land level for agricultural purposes, whereas in Thailand it originated as a multiple use of salt pans. In Indonesia the 'tambak' system of brackish-water culture was probably started in the thirteenth century by convicts who were forbidden to practise agriculture or other professions. Fish culture began in Europe in mediaeval times, mainly in association with monastic houses. In Africa, where it has a relatively recent history, culture of fish in ponds was initiated on a subsistence level by colonial administrations, to improve the nutrition of the natives. In North America, there has been from early times an emphasis on the production of sport fish and fish that have a high market value. The stocking of rivers, lakes, and other water bodies has received special attention in most countries of the Americas. The culture of ornamental fish by the producers always had a commercial basis, although the art of aquarium keeping developed largely for aesthetic reasons.

In spite of such clear differences in patterns of development, present-day interest in aquaculture has a more common orientation and tends to form a unified pattern directed toward the establishment of viable industries, irrespective of social and economic differences. It is now generally believed that many of the natural stocks of fish from the sea or inland waters are not capable of yielding higher catches, but, on the contrary, need strict regulatory measures if even the present production is to be maintained. According to some estimates, the demand of expanding populations of the world for food and animal feed is expected to increase to 107 million tons by 1985 and this, it is believed, cannot by met by increased catches from wild stocks. This is specially so in the case of a number of high-priced species, the stocks of which appear to have been greatly reduced by intensive exploitation. The recent trend has, therefore, been to turn to aquaculture as a means of supplementing the production from commercial fishing. There has been some emphasis on luxury products to meet national demand or to stimulate exports, but in the major aquaculture areas of the world, the main emphasis continues to be on the cultivation of species that have wide acceptance among all social and economic groups in the respective countries, e.g. Chinese and Indian carps in many Asian countries; milkfish in Indonsia, Philippines, and Taiwan; common carp in Israel and east European countries; grey mullets in eastern Mediterranean countries; tilapia in Africa; mussels in Spain; and seaweeds in Japan. Further, species which were at one time considered luxury products are becoming less expensive and common items on the menu in some areas, as for example, rainbow trout in Denmark, Italy, and Greece.

Present Status of Aquaculture

There are many definitions of aquaculture, varying from propagation of aquatic organisms under complete human control, to the manipulation of at least one stage of an aquatic organism's life before harvest, for the purpose of increasing its production and yield. While fish and shellfish husbandry aims at breeding and rearing under fully controlled conditions, enabling complete domestication; as actually practised today, it involves human intervention to reduce the organism's rate of mortality and to improve its growth and reproduction by the provision of favorable conditions.

Aquaculture can be classified on the basis of the purpose or the techniques of culture adopted. The former includes (a) culture for food production, (b) culture to improve natural stocks through artificial recruitment and transplantation, (c) culture for the production of sport fish, (d) culture of bait fish for commercial fishing purposes, and (e) culture of ornamental fish. To this may be added (f) aquaculture for the recycling of organic wastes, and (g) aquaculture for industrial or other purposes, such as raising fish for reduction to animal feed, fish meal or fertilizer, and pearl culture.

VARIETY OF TECHNIQUES

Techniques of aquaculture are expanding rapidly and many modifications and combinations of techniques are being adopted. Classification according to the techniques used is therefore somewhat difficult; however, some major categories can be recognized. Pond culture of fish and shrimps continues to be one of the main types of aquaculture in most parts of the world. Some of the new developments consist of culturing fish in tanks, cages, enclosures, raceways, and recirculating water systems in indoor tanks. The culture of oysters, mussels, and other molluscs forms a distinct type of aquaculture, in this it is generally carried out in estuaries, sheltered coastal areas, or rivers. Traditional bottom culture has been replaced in many areas by hanging or tray type of culture, sometimes referred to as the "three-dimensional" culture in which the entire water column is utilized for production of the animal under cultivation. Although the controlled reproduction of molluscs is coming into use in some areas, most of such culture is still based on seed collected from nature, using suitable substrates. Seaweed culture in sheltered coastal areas in Japan, Korea, and recently Taiwan, also follow the techniques of seed collection from nature.

STOCKING

Stocking of streams rivers, lakes, and reservoirs has been widely practised to improve or establish fish stocks, either to produce more food or to provide sport. The seed for stocking are generally raised in conventional hatcheries and reared to a size when they are less susceptible to predation before release. In cases of successful stocking with anadromous species like salmons and trouts, a satisfactory percentage of the adults return to their home waters and provide a fishery there. Environmental improvement may be possible in streams, small rivers, lakes and reservoirs and these techniques contribute to higher growth, survival and better reproduction of the animals stocked. In fact, in some of the east European countries like Poland and USSR, small lakes are managed like fish ponds, with maximum possible control of water conditions, including fertilization, predator control and other forms of environmental manipulation. Although the efficiency and economics of this form of aquaculture have often been questioned, particularly when hatchlings or early fry incapable of protecting themselves were released in numbers inadequate to produce any noticeable results, several cases of successful stocking operations are now known, as for example, the coho and chinook salmon in the United States and Canada. A mean return of up to 12% of released fish to home waters is obtained for *Salmo salar* in the Baltic, which accounts for a return of $1.6 to every $1 spent on this operation. The release of salmon (*Oncorhynchus* spp.) and steelhead trout (*Salmo gairdneri*) on the Pacific west coast of the United States and Canada, is reported to yield a cost-benefit ratio of 1:2 or 1:3, in spite of the hatcheries not being utilized to their full capacity. The exploitable stocks of Indian carps in the man-made lakes of India have been built up through stocking operations. Stocking and the application of other aquaculture techniques account for the increased production of sturgeons from the reservoirs on the Volga in the USSR and the production of common carp in Polish lakes. Such evidence is not yet available for any purely marine species other than molluscs and therefore critical studies of artificial recruitment undertaken in the Inland Sea of Japan and contemplated in other areas will be awaited with interest.

WORLD PRODUCTION

Due to the lack of adequate data, world production through aquaculture has been difficult to assess. On the basis of information collected by FAO from 36 countries, production by culture of finfish was estimated to be over 3 million tons in 1970 and along with the estimated production of 1 million tons of molluscs constituted a total production of about 4 million tons. A more recent estimate based on updated data from 42 countries (Appendix I) puts production of finfish at about 3.7 million tons, molluscs at about 1 million tons and seaweeds 0.4 million tons. The total world production by aquaculture would thus be over 5 million tons. The production of sport fish and bait fish through aquaculture is not covered by these estimates. The magnitude of the ornamental fish trade is very seldom realized or recorded. In the United States alone, it is estimated that about $80 million (US) worth of ornamental fish are imported annually. Pearl culture is expanding and in Japan over 100 tons of pearls, valued at above $71.5 (US) million, were produced in 1969.

The present aquaculture production has an important role in the food and nutrition of many countries, much greater than the volume of production may seem to suggest. In China, for example, it is reported to constitute at least 40% of the fish and shellfish produced. In India it accounts for about 38% of the total fish production and is a major source of fish supplies in the eastern parts of the country. Indonesia's production of over 266,000 tons forms about 22% of the total catches landed in the country. Milkfish culture alone contributes about 56,000 tons valued at $20.5 million (US) and provides employment for about 520,000 men. In the Philippines it forms about 10% of the total fish production. Although in Japan the total aquaculture production is only 6% by weight of total landings, it contributes about 16% by value. The gross annual income from oyster farming alone is over $4 million (US) in Australia.

In landlocked countries like Nepal and the Central African Republic, fish culture is developing into the main source of fish proteins and has significance out of proportion to the weight or monetary value of the produce. In areas with limited transport facilities or low purchasing power, homestead type of fish culture has still a major role to play. Both subsistence-level as well as commercial-scale aquaculture can greatly improve rural economy of developing countries, by providing employment opportunities to the unemployed and the underemployed, besides improving the nutritional status of the populations. The culture of high-priced species presents opportunities for export and the earning or saving of foreign exchange, which is of special importance in many economies.

PROFITABILITY OF AQUACULTURE

It is often believed that aquaculture is less profitable than fishing, agriculture, or animal husbandry. Due to many reasons cost-benefit data for commercial-scale aquaculture are difficult to obtain and sometimes opinions are expressed on the basis of performance of government stations primarily meant for experimental and demonstration purposes. Some examples of cost-benefit studies of private aquaculture are given in Appendix II. As is evident from the data, there are many factors that affect the profitability of aquaculture and, therefore, the return on investment is bound to vary according to local conditions. However, national comparisons undoubtedly show the relative profitability of aquaculture and indicate the possibility for its development without government subsidies and other types of protection. This is not to suggest that all aquaculture is invariably profitable. As in any other industrial or agricultural activities there are profitable and unprofitable operations, but it would appear that when proven techniques are adopted and installations are properly managed by experienced personnel, the return on investment can be definitely favorable. It is far from surprising that those who invested without proper experimentation and pilot-scale studies often found their operations uneconomic.

A consideration of the major components of cost of production in aquaculture will indicate the reasons for lower profits in some countries. Seed, feed and labor constitute the major items of cost in most types of intensive aquaculture. In the present state of aquaculture development, where the techniques of seed production (often involving collection from nature and transport over long distances) feeding and other culture operations are labor-intensive, the production costs may be uneconomically high in some developed countries. Similarly, under economic and social conditions prevailing in many developing countries, it is feasible — and is often more remunerative — to undertake 'extensive' type of culture instead of 'intensive' culture. Thus, the compatability of the levels of aquaculture under the socioeconomic conditions existing in a country is a significant factor in development planning. For example, it is uneconomic under Israeli conditions to maintain fish ponds that produce less than 2000 kg/ha, and for this, intensive feeding has to be practised. On the other hand, the production of about 1000 kg/ha without feeding is considered more profitable under existing conditions in India.

Role of Aquaculture in Fishery Development

FOOD PRODUCTION

The role aquaculture can play in meeting the increasing demand for human and animal feed has already been referred to. To produce all the fish and shellfish that will be required by the expanding populations in the next decade or so, there appears to be no other means than the utilization of unconventional resources such as the Antarctic krill. Unless there is an unforeseen change in the behavior of human populations, the preference for known food items to meet nutritional needs is likely to continue and therefore the production of acceptable forms of food like the favored species of fish and shellfish will have to be increased.

It is obvious that for meeting food shortage among people with low purchasing power, low-priced fish and shellfish have to be produced. Considering the biological efficiency of protein production and the cost of operations involved, the culture of herbivorous and omnivorous species would be the most suitable means for this purpose. Costs of feeding and in some cases even seed procurement can be minimized in such cases, contributing to a low-cost product. Tilapias, Indian and Chinese carps, grey mullets, milkfish, and mussels are some of the species that are being produced at relatively low cost to meet the food requirements of the common man in many countries. The relative economic efficiencies of 'extensive' as against 'intensive' culture in some countries have already been indicated and decisions in this regard have to be made on the basis of local conditions.

Fish farming has become an integral part of rural development in many developing countries. The history of Chinese fish culture shows how important a part it always had in rural life. By combining fish culture with pig or cattle raising, and in some cases with rice cultivation, the peasants developed integrated farming practices which contributed substantially to their economic and nutritional standards. The practice of duck-cum-fish farming in east European countries significantly contributes to food production and farmers' earnings. The application of these techniques in other areas of the world has given most encouraging results. The introduction of duck raising in combination with fish culture in Nepal has raised earnings per hectare of ponds by at least two times. In the Central African Republic, the raising of pigs in conjunction with fish farming was shown to increase the farmers' earnings by more than three times, with a significant improvement of fish production.

The advantages of rotation of crops including fish and integration of aquaculture in rural development have been clearly demonstrated in a number of countries. Fish culture in community development areas in India, in the Integrated Rural Development Projects in Congo (Brazzaville), and in the Applied Nutrition Programmes in Ceylon, India, Indonesia, Korea, and Lesotho, have demonstrated how it can increase food production and rural earnings, and at the same time make a substantial contribution to meeting the nutritional requirements of rural populations. A three-way rotation of fish, soybeans and rice is now being tried with considerable success by some farmers in Arkansas, USA.

Production of Luxury Foods

As already mentioned, one of the roles of aquaculture development may be to produce high-priced sea-foods, which are in short supply or when cultured are preferred by consumers. Culture of salmon, trout, eel, yellowtail, shrimps, oysters, etc. are examples. Through culture, it may not only be possible to maintain a steady supply of fresh products — many of them even in a live condition — but also to produce them to the desired and uniform size and sometimes even to quality requirements. Although the cost of production of such species is likely to be higher, particularly in developed countries, their market value is also compensatingly high. Developing countries have a special interest in the culture of such species due to export possibilities.

Use of Low Grade Fishery Products and Recycling of Wastes

Aquaculture offers a great potential in converting low grade fishery products into high quality fish or shellfish. In the early forms of fish culture in China, the farmers have depended on domestic wastes for feeding or for the fertilization of ponds. Many forms of conventional fisheries produce large quantities of trash fish, which may not be sufficient to support a reduction industry. These can be efficiently utilized in fish farming. The success of trout farming in Denmark and eel farming in Japan and Taiwan largely depends on the availability of cheap trash fish. Even in some countries where fishing is done to supply reduction industries, there is an increasing demand for utilizing low grade fishery products for human consumption. Fish meal is at present a major component in fish feeds, and in proper formulations contributes to a conversion ratio of feeds (dry weight) to fish (wet weight) in the order of 1.2:1–2:1, which compares very favorably with poultry or beef farming. Fish may therefore be an admirable converter of low-quality fish to high-quality human food.

Use of domestic wastes is an ancient practice in fish culture and the very high production obtained in sewage farming shows its advantages. Recycling being probably the most efficient form of waste disposal, the use of organic wastes in aquaculture is of special importance. The aesthetic objection to fish or shellfish cultured in sewage-fed areas can be overcome by proper consumer education as has been done in some countries where even drinking water is derived from sewage effluents. It should be possible to overcome any possible public health hazards by appropriate modifications in culture techniques or monitoring and treatment of wastes. The technique of using sewage for raising algae, which is directly introduced as food for cultivated organisms or used as a major component for the production of compounded feeds, is of special interest in this regard. If there is a need to increase the production of industrial fish for fish meal or fertilizer manufacture, it is quite conceivable that a prolific species like the tilapia, capable of yielding several crops of small fish every year, can be cultivated in sewage oxidation or stabilization ponds, contributing substantially to solving the waste disposal problem, as well as to the production of raw material for a reduction industry.

Employment Potential

The labor-intensive nature of many of the present forms of aquaculture has already been referred to. While in areas where there is a scarcity of labor, this is likely to be increasingly modified by mechanization of operations, in others it gives part-time or full-time employment to those in need of it. In the resettlement of populations as a result of the decline of fishing or other fishery activities, as in the case of lagoon fishermen in Mauritius or estuarine fishermen in parts of India, aquaculture deserves special consideration. Man-power requirements vary with the type of culture and techniques adopted. Twenty hectares of fish ponds generally need four to five full-time laborers, besides part-time labor during harvesting and when major repairs are to be undertaken. In oyster and mussel farming, a rough estimate of full-time workers needed may be two to four per hectare in traditional type of operations and three to five per 100 ha in mechanized farming. Considering the extent of areas available for aquaculture development in many developing countries, the employment potential in this industry would appear to be very significant. In Korea, for example, it employs about 130,000 full-time and some 300,000 part-time workers. In the Philippines, over 170,000 people, and in

Indonesia about 520,000 people are employed in this industry.

Role of Aquaculture in Fishery Management

As far as capture-fishery management is concerned, the major role of aquaculture could be in relieving the pressure on the wild stocks by developing additional sources of supplies. It could serve to meet the demand for some of the highly priced species which capture fisheries are unable to meet. In view of the world demand for fishery products, there is unlikely to be any real competition between aquaculture and capture fisheries; on the contrary, they could be complementary, and even serve to diversify the operations of fishing companies.

Another significant aspect of aquaculture development in relation to fishery management, is the fact that most types of culture can be undertaken within national jurisdiction, and that there are fewer chances of international conflicts with regard to rights and ownership in culture fisheries, than is often the case in oceanic fishing. Aquaculture can be developed and managed to meet national requirements for local consumption or for export, in the coastal, estuarine and freshwater areas where natural resources are recognized to be national property. The only major exceptions to this would be the fishing in the open seas of migratory stocks like those of salmon produced by aquaculture.

Aquaculture operations can in many cases be programed to meet off-season demands as is already being done in some countries. Most of the commercial fisheries are of a seasonal nature and during the off-season the availability of fresh produce is very much reduced and the market price increases considerably. Aquaculture can, therefore, contribute to the stabilization of market conditions and increase the production of fish and shellfish of the desired qualities. Fish can be grown to the size preferred by the consumers and by manipulating the feed, fattiness can be controlled. As fish and shellfish produced through aquaculture are not subject to size restrictions, as in capture fisheries, the products can be sold at a smaller size if preferred by consumers, as for example, 'pan size' salmon, small abalone, etc. Already some success has been achieved in improving the colour of the flesh through the use of special feeds. Carp breeders have used selection techniques for body conformation to meet consumer preference in countries like Germany. Studies are now underway to develop a carp with fewer fine bones. With the development of genetic selection and hybridization, one can visualize exciting possibilities in improving the quality of aquatic products.

Reference has already been made to artificial recruitment using aquacultural techniques. Although there is a need for more well planned and large-scale experiments to determine their efficiency, transplantation and 'seeding' are undoubtedly potential means of stock improvement. Well-planned transplantations can contribute to building up new exploitable populations, or improving the genetic quality of existing stocks.

Aquaculture has the possibility of developing into an important auxiliary industry for commercial fishing through baitfish production. Already this is well developed in countries like the United States to meet sport fishing requirements. In the state of Arkansas alone over 6000 ha are under bait minnow culture, producing over 2.1 million kg of bait, valued at over $5.3 million (US). In commercial fishing, this is still in an experimental stage. Among the cultivated species, the tilapia has been tried as live bait, but the milkfish seems to hold more promise. Further research may lead to identification of other species of cultivable baitfish, and the development of suitable techniques for their mass rearing. The possibility of producing fish for reduction industries through culture has already been mentioned. Rapidly reproducing species can be grown in sewage-fed ponds or other impoundments, yielding several crops a year, amounting to a production of at least 10 tons per ha at low cost.

In a discussion of the role of aquaculture in fishery management, consideration has also to be given to some of the possible adverse effects on commercial fisheries. One that has received some attention is the effect of converting saline swamps and lagoons into fish ponds. Some of them may be important nursery grounds for marine fish and crustaceans and the loss of access to such regions can affect the survival of juveniles and the recruitment to commercial fish stocks. However, it should be possible to resolve any such conflicts in the use of potential sites. On the basis of data on annual recruitment to commercial stocks for which the swamps and lagoons form nurseries, the estimated survival rates before recruitment, and the approximate nursery space requirements, a policy of zoning of such areas for multiple use could probably be evolved.

Since culture of many species is still based on larvae or juveniles collected from nature, it is often argued that large-scale aquaculture of this type may affect the magnitude of wild stocks. Although such an eventuality cannot be ruled out, there appears to be no evidence of the wild stocks of cultivated species such as the Indian and Chinese carps, milkfish, eels, and grey mullets, having been affected as a result of large-scale fry collection. In view of the high percentage of natural mortality that normally occurs in nature in the early stages of these species, and the small proportion of the larvae or juvenile population collected, it is believed that such effects are not likely to be of any great significance. Further, with the advance of aquaculture technology, controlled breeding of species will become more common and collection from nature may become only a minor source of seed supplies.

The possibility of aquaculture being a source of aquatic pollution has received some attention lately. Increasing silting caused by the installation of large series of cages or rafts in restricted bodies of water with low circulation, and the effects on aquatic organisms when water from ponds treated with herbicides or fish poisons is immediately flushed into streams, are the two possible major adverse environmental consequences. Suitable procedures to prevent both these types of effects are known. Further, it has been suggested that any organic effluents from aquaculture installations should be recycled and used for raising algae and other food organisms for cultured stocks.

It is sometimes asked whether large-scale development of aquaculture will be in competition with conventional fishing. Although aquaculture would contribute to stabilizing market conditions, it is difficult to conceive of any real competition between these two forms of production. In view of the increasing world demand for fishery products, and the complementary nature of many of the operations, in all probability aquaculture can be only of overall benefit to commercial fishing.

Potential for Aquaculture Development

AREA AVAILABLE FOR AQUACULTURE

A world-wide survey of potential sites for aquaculture has not yet been undertaken, although some of FAO's regional fishery bodies are initiating such studies. Swamps and low-lying areas with assured sources of water supply are generally selected for pond construction. Data so far collected show that about 2.2 million ha are now under pond culture of finfish (Appendix I), and this forms only a small percentage of the potential areas available, as can be seen from the figures for 11 countries in Asia (Appendix III). There are extensive saline swamps along the estuaries and coasts of Africa and Latin America which can be converted into fish ponds. A survey conducted in the Niger delta showed that there are some 1.8 million acres (729,000 ha) of mangroves out of which at least 1 million acres (405,000 ha) could be readily reclaimed for fish culture. Kesteven (1972) estimates the extent of lagoons and mangrove swamps in the world to be between 10 and 20 million ha and a good percentage of these may be suitable for aquaculture. It has to be recognized that in some industrially advanced countries, there may be other important demands for aquaculture sites, particularly foreshore areas, and ownership and conflict of interests may preclude their use. In spite of this, it can safely be assumed that at least a tenfold increase in area under pond culture can be obtained by utilizing sites readily available in Asia, Africa, and Latin America.

The use of small lakes, 'dams,' and reservoirs for fish culture is increasing and the area of such waters is only likely to increase with the development of new irrigation and power projects. The area of small reservoirs (less than 1000 ha in most cases, except for the USSR where reservoirs up to 10,000 ha are included) used for fish culture in some countries is shown below:

Area of small reservoirs presently used for fish production through stocking

	ha
USSR	273,000
Poland	270,000
India	250,000
Bangladesh	142,500
Malaysia	13,200
Madagascar	6,600
Philippines	5,700
Total	961,000

Rice field fish culture, though an important means of food production, has had a setback in some countries due to the widespread use of certain pesticides. With the increasing emphasis on the use of less harmful pesticides, interest is reviving in this practice. There are some 61,000 ha of rice fields already being used for fish culture in Indonesia and this area can be considerably expanded. Rice field prawn farming in India and carp and tilapia farming in the rice fields of Madagascar are capable of further expansion. According to an estimate made in 1967, if at least 30% of the existing 88 million acres (35.6 million ha) of rice fields could be used for culture of fish also, even at a very low rate of production, an approximate yield of 2.2 million tons of fish could be obtained (President's Science Advisory Committe 1967).

Cage culture and culture in enclosures adapted for open and running water conditions, can be practised in streams, rivers, canals, lakes, reservoirs, estuaries, lagoons, bays, and coastal areas with adequate protection from high waves and winds. An estimate of suitable areas for this type of culture has not yet been made, but obviously this will run into many millions of hectares.

Oyster and mussel culture is largely located in protected coastal and estuarine areas. Although aquatic pollution tends to reduce the availability of suitable sites, there are undoubtedly very extensive areas available all over the world, particularly in developing countries. Considering the very high production that can be obtained per unit area in this type of culture under favourable conditions, e.g. 10 to 50 thousand kg of mussel meat per hectare (not including the area that contributes to producing food for the mussels), the requirements of space, if sufficiently productive, need not be great. The indoor 'industrial' type of aquaculture is still in its very early infancy, though developments on these lines can be large when the necessary technology has been evolved. Installations for such types of culture will, necessarily, be located on land.

In view of the great present-day interest in developing tourism and the explosion of recreational industries in all parts of the world, sport fishing is bound to increase at a rapid pace. Most streams, lakes, and reservoirs in the neighborhood of tourist resorts are potential sites for this type of aquaculture. Also any water body located in an attractive area where sport fisheries could be developed, has the potential to become an important tourist resort.

Although the data available are far from complete, it is clear from the foregoing that there are adequate areas available for a many-fold expansion of aquaculture in most parts of the world, particularly in developing countries.

ESTIMATES OF FUTURE PRODUCTION

It is extremely difficult to make any reliable estimate of future production through aquaculture, as it will to a large extent depend on the importance that the governments and the industry give to this form of food production, and the investment of money and effort that goes into its expansion. Rapid developments, which were mostly unforeseen, have taken place in aquaculture production in recent years. Examples are catfish farming in the United States, eel farming in Japan, oyster farming in Korea, and trout farming in Italy and Greece.

The President's Science Advisory Committee in the United States in a report on the food problem (1967) predicted an increase in yield of 15 million tons through pond culture alone by the year 2000, "if research can provide the management inputs." FAO's Indicative World

Plan for Agricultural Development (1969) considered an expansion factor of five by the year 1985 as feasible, and according to this, the world annual production through aquaculture by that year may be around 20–25 million tons. Bardach and Ryther (1968) estimate a higher rate of increase of ten times by the year 2000, which would mean a world production of 40–50 million tons annually.

Increases in production can occur as a result of the expansion of areas under cultivation and of the improvement and intensification of culture techniques. The possibility of not less than a 10-fold expansion in the area for pond culture has already been referred to. Expansion of other types of culture seem to be limited mainly by the lack of organization, expertise and investment. It is, for example, most probable that there will be spectacular increases in production by the introduction of modern mussel farming techniques in tropical waters. This could amount to appreciable quantities, if the production per hectare is anywhere near what is now obtained in Spain.

CONSTRAINTS ON DEVELOPMENT

A major constraint on the development of aquaculture would appear to be the misconceptions that are fairly widespread. It is often believed that aquaculture is still in the experimental stage; that it is only for the production of luxury foods and is not capable of contributing to the production of animal proteins for the people who need them most; and that aquaculture operations are uneconomical. Some of the data presented in this paper will show that aquaculture is already contributing very substantially to the economy and food production in a number of countries and the economic viability of many types of cultures under suitable conditions has been demonstrated. Many new developments in technology and consequent increased production, as well as reduction in the cost of production are expected as a result of experimental work that is being currently undertaken. An accelerated program of research is needed to solve some of the problems encountered, particularly in new types of aquaculture, such as shrimp and marine fish culture; but there is already enough knowledge to expand culture fisheries in many parts of the world.

A number of failures in aquaculture can be traced to the lack of trained personnel. Even in countries where aquaculture already is an important industry, there has been very little broad-based planning for future development. Although the situation shows signs of change in some countries, unfortunately aquaculture has not received, as yet, sufficiently high priority in development planning. For differing reasons, individuals and private companies have, of late, shown considerable interest in this subject, specially in developed countries. Those who realized the need for pilot-scale studies and the type of investment and time required to obtain profits, appear to be on the road to establishing a profitable industry. Action by the private sector, due to its proprietary nature, has, unfortunately, not spread very far and has contributed little to the overall development of the industry.

Conflicts do exist between aquaculture and recreation, industrial and aquacultural development, water resource and residential developments, etc., but it is also possible to find resource use compromises, if a policy for compatible multiple use of coastal zones and other potential aquaculture sites is adopted.

Aquatic pollution has become a very significant limiting factor in aquaculture development, especially in industrially advanced countries. It is reported that 8–10% of oyster culture grounds in the United States have been closed as a result of sewage and industrial pollution, and in the Inland Sea of Japan, 20–30% of the aquaculture areas has been rendered unfit for fish or shellfish culture by eutrophication. This problem is becoming acute in other areas of the world also, and suitable pollution control measures are needed to permit aquaculture development. Experimental studies in the use of thermal effluents from power stations have shown that aquaculture can be a safe means of waste disposal and can result in greatly increased production of fish and shellfish in temperate and subtropical countries. This technique is now being employed on a commerical scale in some countries of eastern Europe.

REQUIREMENTS FOR RAPID DEVELOPMENT

A review of aquaculture techniques would readily show a number of gaps in our knowledge, which indicates the need for more research on the subject. Despite almost a 4000-year history, the present technology has mostly been developed by trial and error, rather than scientific research. To modernize and intensify culture operations to suit conditions in different regions of the world, there is undoubtedly an urgent need for concerted and well-organized research. The major elements in the cost of production in aquaculture are: 'seed,' labor, and feed. Research has to be concentrated on reducing these costs to maximize profits. Controlled breeding of the cultivated animals is of prime importance for an assured supply of 'seed,' the qualities of which could be greatly improved by the use of genetic selection and hybridization techniques. One of the main clues to intensive culture is artificial feeding and studies on the nutrition of cultivated animals, and the preparation of suitable feeds at reasonable costs are therefore of high priority. A main risk involved in aquaculture is loss through diseases and parasites. Research on the diagnosis and treatment for the control of these is therefore of importance. Engineering aspects of aquaculture have been a neglected field. Since the main capital investment in aquaculture relates to the construction of impoundments, enclosures or other types of installations, design and experimental work to improve their efficiency and reduce costs, is essential. In fact, aquaculture calls for expertise in different branches of science, including biology, genetics, parasitology, soil science, chemistry, feed technology, engineering, and economics. An interdisciplinary research effort can therefore significantly contribute to its rapid development.

The scarcity of trained aquaculture personnel has already been referred to. There is a need for scientists as well as technicians and extension workers. Unfortunately, there are very few well-equipped centers for education and training in this field and the majority of aquaculturists today are those who obtained mostly on-the-job training. An intensive development program cannot depend on such an arrangement and suitable facilities for the education and training of different levels of personnel will need to be organized on a national or regional basis.

Rapid progress in aquaculture would seem to require a development strategy in the framework of national fishery development plans. Based on realistic phased production targets, the necessary infrastructure has to be built and appropriate provision made for financing. In the absence of proper organization and specially of extension support, few large-scale aquaculture programs can be expected to succeed. There have been many instances of projects initiated without the provision of basic requirements for success, resulting in failures, and these being taken as proof that such projects are not feasible. It is therefore of special importance that adequate planning effort precedes aquaculture development programs. Experiments should be followed by pilot-scale studies and on the basis of their results, development plans formulated and implemented with essential infrastructure for efficient operations and support. If these requirements are met, it may be reasonable to expect that aquaculture would develop in many parts of the world, to make a significant contribution to world food production.

Appendix I

Estimated World Production Through Aquaculture, in Metric Tons

(All estimates are not for the same year. In all cases the most recent figures available have been used.)

PRODUCTION OF FINFISH

Country	Area (*ha*)	Production (*t*)
China (Mainland)	700,000	2,240,000
India	607,915	480,000
USSR	–	190,000
Indonesia	266,300	141,075
Philippines	164,414	94,573
Thailand	–	87,764
Japan	508	85,000
Taiwan	39,234	56,185
USA	28,300	40,200
Pakistan and Bangladesh	30,780	37,540
Malaysia	90,473	25,648
Hungary	22,000	19,697
France	110,000	23,000
Italy	–	18,000
South Vietnam	2,500	16,500
Yugoslavia	9,747	15,840
Ceylon	10,000	15,000
Rumania	6,400	12,000
Denmark	–	11,000
Poland	62,791	10,909
Czechoslovakia	42,798	10,641
Israel	4,904	10,220
Brazil	–	9,967
Mexico	12,650	9,026
Khmer	–	5,000
Germany, East	–	3,669
Germany, Federal Republic	11,824	2,627
Burma	2,920	1,494
Zaire	4,058	1,406
Bolivia	25,502	1,400
Austria	3,000	780
Hongkong	629	690
Zambia	–	689
Uganda	410	670
Madagascar	1,280	615
Norway	–	600
Singapore	890	554
Nigeria	–	127
Kenya	610	122
Spain	–	50
South Korea	76	40
Ghana	204	30
Puerto Rico	135	25
	2,263,252	3,680,373

PRODUCTION OF SHRIMPS AND PRAWNS

Country	Area (*ha*)	Production (*t*)
India	4,000	3,800
Indonesia	–	3,328
Philippines	–	2,500
Thailand	–	2,500
Japan	–	1,800
Malaysia	870	250
Singapore	–	120
Total		14,298

PRODUCTION OF MOLLUSCS

Country	Production (*t*)
Oysters	
United States	350,500
Japan	194,600
Korea	45,700
Mexico	43,500
France	34,200
Taiwan	12,700
New Zealand	10,700
Australia	9,800
Canada	4,100
Portugal	2,900
Spain	1,800
Total	710,500
Mussels	
Spain	109,700
France	39,800
Korea	16,800
Italy	13,700
Total	180,000
Clams	
Malaysia	28,600
Korea	16,800
Japan	10,800
Taiwan	60
Total	56,260
Miscellaneous	
Korea	19,700
Total for molluscs	966,400

PRODUCTION OF SEAWEEDS

Country	Production (*t*)
Japan	357,000
Korea	16,000
Total	373,200
Grand total	5,034,331

Appendix II

Cost-Benefit Data of Some Examples of Aquaculture Operations

(Capital costs are based on current value)

I. Data on a 35 acre (14.16 ha) rainbow trout pond farm in Ireland in 1970 (source: FAO/EIFAC files)

		£	%
A.	Capital investment		
	1. Value of land	18,000	x
	2. Construction of ponds	17,000	x
	Total	35,000	
B.	Operating costs		
	1. Stocking material	1,500	13.0
	2. Feeds	6,000	51.9
	3. Other materials	40	0.3
	4. Labor	2,000	17.4
	5. Maintenance and repairs	200	1.7
	6. Other costs	1,000	8.7
	(Transport to markets)	(1,000)	(8.7)
	7. Depreciation	800	7.0
	Total	11,540	100.0

C.	Income	24,000	
D.	Profit	12,460	
	1. Ratio to operating costs		107.9
	2. Gross income		51.9
E.	Ratio of profit to operating costs — depreciation excluded		
	Ratio to operating costs		116.0

II. Data on rainbow trout culture in 162 m^3 floating enclosures in Norway, 1969 (source: FAO/EIFAC files)

		Kr.	%
A.	Capital investment		
	1. Construction of ponds	1,700	x
	2. Equipment	15,000	x
	Total	16,700	
B.	Operating costs		
	1. Stocking material	4,800	28.4
	2. Labor (including fishing for trash fish used as feed)	8.000	47.3
	3. Maintenance and repairs	2,000	11.8
	4. Other costs	1,800	10.7
	(Transport to markets)	(1,800)	(10.7)
	5. Interest on loans	300	1.8
	Total	16,900	100.0

C.	Income	33,000	
D.	Profit	16,100	
	1. Ratio to operating costs		95.2
	2. Gross income		48.7
E.	Profit + interest on loans	16,400	
	1. Ratio to operating costs		97.0
	2. Gross income		49.6

III. Data on common carp culture in a 555 ha state farm in Poland, 1969 (source: FAO/EIFAC files)

		Zloty (thousands)	%
A.	Captial Investment		
	1. Construction of ponds	18,659	x
	2. Equipment	6,667	x
	Total	25,326	x
B.	Operating costs		
	1. Stocking material	74	1.7
	2. Feeds	1,722	39.4
	3. Fertilizers	182	4.1
	4. Other material	10	0.2
	5. Labor	1,172	26.8
	6. Pesticides	–	x
	7. Maintenance and repairs	314	7.2
	8. Other costs	418	9.6
	9. Depreciation	465	10.6
	10. Interest on loans	18	0.4
	Total	4,375	100.0

C.	Income	5,665	
D.	Profit	1,290	
	1. Ratio to operating costs		29.4
	2. Gross income		22.7
E.	Profit + interest on loans	1,308	
	1. Ratio to operating costs		29.8
	2. Gross income		23.0
F,	Ratio of profit to operating costs — depreciation excluded		
	1. Ratio to operating costs		32.9

IV. Data on the culture of Indian carps in a 3.5 ha freshwater pond in West Bengal, India 1971 (source FAO/IPFC files)

		Rupees	%
A.	Capital Investment		
	1. Value of land	40,000	x
	2. Construction of ponds	49,000	x
	3. Equipment (nets)	1,022	x
	Total	90,022	x
B.	Operating costs		
	1. Stocking material	20,000	44.2
	2. Feeds	144	0.3
	3. Fertilizers	2,500	5.5
	4. Labor	14,900	32.9
	5. Pesticides	12	x
	6. Maintenance and repairs	140	0.3
	7. Other costs	7,626	16.8
	(Handling and marketing of fish)	(476)	(1.0)
	Total	45,322	100.0

C.	Income	58,400	
D.	Profit (Income—Operating costs)	13,078	
	1. Ratio to operating costs		28.8
	2. Gross income		22.3

V. Data on polyculture of grey mullet and Chinese carps in a 1 ha farm in Hongkong, 1972 (source: FAO/IPFC files)

		US$	%
A.	Capital investment		
	1. Value of land (rented land – see operating costs)	–	x
	2. Construction of ponds	19,000	x
	3. Equipment	4,011	x
	Total	23,011	x
B.	Operating costs		
	1. Stocking material	1,123	7.6
	2. Feeds	5,769	39.0
	3. Fertilizers	538	3.6
	4. Labor	1,938	13.1
	5. Maintenance and repairs	1,923	13.0
	6. Other costs	3,501	23.7
	(Annual rent of land)	(3,000)	(20.3)
	Total	14,792	100.0

C.	Income	23,692	
D.	Profit	8,900	
	1. Ratio to operating costs		60.1
	2. Gross income		37.5

VI. Data on milkfish in a 5 ha farm in Bulacan, Philippines, 1972 (source: FAO/IPFC files)

		Pesos	%
A.	Capital investment		
	1. Value of land	150,000	x
	2. Construction of ponds	27,250	x
	3. Equipment	470	x
	Total	177,720	x
B.	Operating costs		
	1. Stocking material	4,500	37.5
	2. Feeds	3,825	31.9
	3. Fertilizers	1,594	13.3
	4. Labor	1,234	10.3
	5. Maintenance and repairs	750	6.3
	6. Other costs	84	0.7
	Total	11,987	100.0

C.	Income	27,068	
D.	Profit	15,081	
	1. Ratio to operating costs		125.7
	2. Gross income		55.6

VII. Data on yellowtail culture in net cages in Japan (source: Furukawa 1971)

		US$	%
A.	Capital investment	536	x
B.	Operating costs		
	1. Stocking material	556	8.1
	2. Feeds	4,167	61.3
	3. Other material	598	8.7
	4. Labor	1,167	17.1
	5. Maintenance and repairs	138	2.0
	6. Other costs	78	1.2
	7. Depreciation	106	1.6
	Total	6,810	100.0

C.	Income	8,673	
D.	Profit	1,863	
E.	Ratio of profit to:		
	1. Operating costs		26.6
	2. Operating costs – depreciation excluded		26.9

VIII. Data on channel catfish farming in a 160 acre (64.8 ha) farm in Mississippi, USA (source: Mitchel and Usry 1967)

		US$	%
A.	Capital investment		
	1. Value of land	62,370	x
	2. Construction of ponds	50,830	x
	3. Equipment	22,190	x
	Total	135,390	x
B.	Operating costs		
	1. Stocking material	16,300	27.3
	2. Feeds	21,787	36.6
	3. Fertilizers	1,113	1.9
	4. Other materials	660	1.1
	5. Labor	4,750	8.0
	6. Pesticides	2,968	5.0
	7. Other costs	6,465	10.8
	(Harvesting)	(4,380)	(7.3)
	(Insurance)	(258)	(0.4)
	8. Depreciation	5,552	9.3
	Total	59,595	100.0

C.	Income	102,200	
D.	Profit	42,605	
	1. Ratio to operating costs		71.4
	2. Gross income		41.6
E.	Ratio of profit to operating costs – depreciation excluded		
	1. Ratio to operating costs		78.8

IX. Data on Penaeid shrimp culture in a 8 ha farm in Thailand (source: Sribhibhadh *in* Coastal Aquaculture 1970) (No capital investment shown, as old saltpans are used for culture)

		Baht	%
A.	Operating costs		
	1. Labor	6,600	32.2
	2. Maintenance and repairs	3,200	15.5
	3. Other costs	5,300	25.7
	4. Depreciation	1,580	7.7
	5. Interest on loans	3,900	18.9
	Total	20,580	100.0

B.	Income	32,750	
C.	Profit	12,170	
	1. Ratio to operating costs		59.1
	2. Gross income		37.1
D.	Profit + Interest on loans	16,070	
	1. Ratio to operating costs		78.0
	2. Gross income		49.0
E.	Ratio of profit to operating costs — Depreciation excluded		
	1. Ratio to operating costs		64.0

X. Data on Penaeid shrimp culture in Japan (source: Furukawa 1970 — Capital costs and area of farm not known — Values in $ calculated on the basis of an exchange rate of 360 yen to a US$)

		US$	%
A.	Operating costs		
	1. Stocking material	2,778	5.3
	2. Feeds	10,598	20.2
	3. Other material	1,874	3.6
	4. Labor	10,621	20.2
	5. Maintenance and repairs	7,836	14.7
	6. Other costs	17,053	32.3
	(Transport to markets)	(6,950	(13.1)
	7. Depreciation	1,927	3.7
	Total	52,687	100.0

B.	Income	74,160	
C.	Profit	21,473	
	1. Ratio to operating costs		40.7
	2. Gross income		28.9
D.	Ratio of profit to operating costs — Depreciation excluded		
	1. Ratio to operating costs		42.3

XI. Data on oyster culture in Japan (source: Furukawa 1970) (No capital investment given. The area under culture is about 1000 m^2. Value in $ calculated on the basis of an exchange rate of 360 yen to a US$)

		US$	%
A.	Operating costs		
	1. Fishing gear, maintenance and repairs	1,409	17.5
	2. Other equipment and fuel	123	1.6
	3. Labor	3,693	45.7
	4. Other costs	1,261	15.7
	(Marketing)	(326)	(4.0)
	5. Depreciation	1,580	19.5
	Total	8,066	100.0

B.	Income	9,344	
C.	Profit	1,278	
	1. Ratio to operating costs		15.8
	2. Gross income		13.6
D.	Ratio of profit to operating — Depreciation excluded		
	1. Ratio to operating costs		19.7

Appendix III

Area Available For Pond Culture in Some Southeast Asian Countries

Country	Present status of culture		Potential			
			Fresh water			Brackish and salt-water swamps and other tidal lands (*ha*)
	Area under cultivation (*ha*)	Production (*t*)	Swamps and floodlands (*ha*)	Small reservoirs (*ha*)	Irrigated rice fields (*ha*)	
Bangladesh	–[a]	–[b]	293,000	142,500	3,900,000	166,000
Burma	2,920	1,484	5,957,000	–	5,000,000	520,000
Ceylon	10,000	15,000	80,000	58,000	300,000	140,000
India	607,915	480,000	480,000	250,000	67,000,000	2,000,000
Indonesia	266,300	141,075	1,760,000	27,000	3,000,000	6,000,000
Malaysia	90,473	25,648	182,000[b]	13,150	227,000	–
Pakistan	30,780[a]	37,540[a]	650,000[b]	32,000	–	–
Philippines	164,414	94,573	126,248	5,720	721,095	381,412
South Korea	76	39	–	220,000	714,000	232,000
Taiwan	39,234	56,185	–	–	533,000	53,871
Thailand	–	87,764	1,762,692	214,742	4,100,000	166,000
Total	1,212,112	939,308	11,290,940	963,112	85,495,095	9,659,283

[a] Cultivated area and production for Bangladesh and Pakistan are combined.

[b] Data include brackish and saltwater swamps and other tidal lands.

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Alternatives in Aquacultural Development: Consideration of Extensive Versus Intensive Methods[1,2]

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For animal species having apparent potential for economical culture, the alternatives of developing extensive or intensive cultural practices are compared. Extensive culture is defined as raising fish or shellfish in natural bodies of water with few modifications of the environment, while intensive culture is defined as rearing animals in man-made ponds, raceways, or tanks where environmental control is exercised. A discussion of legal, biological, economic, environmental, and social implications of each approach is presented. It is concluded that, for most carnivorous and omnivorous species of interest to aquaculturists, expenditures for the development of extensive culture methods are not justified.

L'auteur compare les différentes méthodes à envisager pour développer, soit par des méthodes extensives, soit par des méthodes intensives, l'exploitation des espèces animales qui semblent offrir un potentiel économique. On entend par pisciculture extensive l'élevage de poissons ou de crustacés dans des masses d'eau naturelle, avec peu de modifications de l'environnement, tandis que la pisciculture intensive s'entend de l'élevage dans des lacs artificiels, des passes à poisson ou des viviers, dans lesquels le milieu est strictement aménagé. L'ouvrage analyse les incidences juridiques, biologiques, économiques et sociales de chaque formule, ainsi que ses effets sur le milieu. L'auteur conclut que, pour la plupart des espèces carnivores et omnivores qui intéressent les spécialistes, l'octroi de crédits au développement de l'aquiculture extensive n'est pas justifié.

Se estudian algunas especies animales que ofrecen posibilidades de cultivo en buenas condiciones económicas, y se comparan dos posibilidades: el cultivo extensivo y el intensivo. Por cultivo extensivo se entiende la cría de peces o mariscos en masas naturales de agua, con pocas modificaciones del medio ambiente, mientras el cultivo intensivo se define como la cría de animales en estanques artificiales, canales o tanques, donde existe un considerable control del medio ambiente. Se examinan los efectos jurídicos, biológicos, económicos, ambientales y sociales de cada uno de los dos métodos. El autor concluye que, en el caso de la mayoría de las especies carnívoras y omnívoras que interesan a los acuicultores, los gastos necesarios para aplicar los métodos de cultivo extensivo no están justificados.

Two Types of Aquaculture

EVEN though the immediate potential of aquaculture has been frequently overstated and commercially viable operations have not developed as rapidly as anticipated, interest in aquaculture remains strong. Because of this intense continuing interest, aquacultural research will probably receive considerable financial support over the next few years in both the developing and developed parts of the world.

If sizable expenditures are to be made on aquaculture, some important decisions need to be made concerning the long-term direction of this research and development. Considerable divergence of opinion exists concerning the types of animal husbandry most likely to be successful for aquatic animals. The goals of development programs range from the stocking and harvesting of animals in their natural environment to refined culture systems in which complete environmental control is exercised. The approaches to these divergent types of aquaculture are necessarily different and the probability of economic success varies for a given species depending on the approach used. Although we cannot precisely define these probabilities as present, it is imperative that we examine available information in an effort to predict the most productive developmental paths.

In this discussion extensive and intensive approaches to animal aquaculture will be compared. Extensive aquaculture is defined as raising fish or shellfish in natural bodies of water with few or no modifications of the environment; intensive aquaculture is defined as rearing animals in man-made ponds, raceways, or tanks where considerable

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environmental control is exercised. These two general approaches will be discussed with reference to problems of legal, biological, economic, environmental, and social nature. Because no clear distinction exists between these several categories, an arbitrary classification of problems has been used for discussion purposes.

Legal Aspects

While ownership of land is not a problem if no public waters are involved, it may be a serious one in extensive culture operations. In most states in the United States navigable waters and those influenced by tidal action are considered property of the state. Frequently land adjacent to these waters is also public property. While legal problems are different in each country, the difficulty in obtaining control of bodies of natural water through lease or purchase is a factor of major importance. Intensive culture can be accomplished in most cases on private land for which ownership is clear.

In navigable waters of the United States, restriction of free passage by an extensive culture operation may be illegal. Again the seriousness of the problem will vary with the particular situation, but no problem exists for intensive culture operations.

The ownership of wild animals may be a source of concern when wild juveniles are used for stocking or when wild predators or competitors are killed to protect cultured stocks. For one type of extensive aquaculture — that of stocking hatchery-reared young in their natural environment — ownership problems may be complex and may even become international in scope. Within the United States wild animals are usually considered the property of the state. Minor legal changes, if implemented, could resolve the problems of ownership of wild animals on the national level. Regulations concerning methods of harvest and minimum legal sizes are special problems that would be resolved if the farmer has clear ownership of the animals he is rearing. Until resolved, these problems are more restrictive of extensive than of intensive culture practices.

Biological Aspects

Five biological factors examined here are feeding, environmental control, disease, density, and genetics. There are many interactions between various biological factors, and a thorough examination of all factors is not possible here. The key problems to be considered in comparing extensive and intensive approaches can, however, be included in one of the five following categories.

FEEDING

It has been popular to compare sea farming with agriculture and to point toward possible achievements in the sea parallel to those advancements we have seen in modern agriculture. In making this comparison two important facts are frequently overlooked. First, animal husbandry should not be confused with agronomy. Aquaculture of fish and shellfish may be compared with livestock raising, since both are animal husbandry, but the farming of plant crops involves entirely different concepts than animal aquaculture. Second, traditional animal husbandry for human consumption involves primarily herbivores, while many of the high-priced fish and shellfish considered for aquaculture are carnivores.

Two types of animal husbandry are in common practice, ranching or pasturing of herbivores and feed-lot operations. Ranching procedures extend from the practice of allowing animals to feed on natural range to the cultivation of suitable plant species in pastures. Feed-lot operations include all animal husbandry in which the nutritional requirements of the animals are provided in the feed. From an economic point of view feed costs constitute a large proportion of the expenses of rearing animals under intensive conditions. This cost is either reduced or eliminated when animals utilize natural foods. The substitution of natural foods for prepared diets represents a substantial economic advantage in favor of extensive systems.

The animals most commonly raised for human consumption are herbivores (cattle, sheep, and goats) and omnivores (hogs and poultry) which can also thrive on a vegetable diet. Many of the high-priced fish and shellfish being cultured, for example shrimps, eels, trout, plaice, and catfish, are either carnivores or omnivores. We cannot expect, based on our experience with agriculture, to raise these animals in a ranching style if they feed on other animals rather than on plants. Ranching has been successful only with herbivores. The additional complications and energy losses involved in raising animals as feed for other animals make this procedure prohibitively expensive. Generally, this approach is not being used in agriculture.

A few herbivorous species such as oysters, mussels, and milkfish are of interest to aquaculturists, and some of these species can be cultured at high densities on the natural flora present in the water. However, except for the limited culture of algae for human consumption by the Japanese, we have practically no experience in the cultivation or control of aquatic plants or algae in natural waters. Most aquatic ranching or pasturing operations will, for the present, be limited to those herbivores that can make use of plant life present in natural waters.

The implications of an animal's food requirements to its relative suitability for intensive or extensive culture are obvious. The higher the trophic level of the cultured animal the more complex a natural food scheme becomes, and the more dependent the animal becomes on supplemental feeding. Generally, more control over feed and environmental conditions is required to duplicate complex systems than to duplicate simple systems. The need for supplemental feeding is also related to the variety of food items eaten by the animal and the density of the animals being cultured. Omnivores such as catfish and shrimp can be compared with chickens; at low densities they can forage effectively on natural foods but at most commercially attractive densities supplemental feeding is necessary.

ENVIRONMENTAL CONTROL

In examining the major factors in an animal's environment as they pertain to intensive and extensive culture, parameters such as temperature, water quality, other animals, and plant life must be considered.

The desirability of controlling environmental factors can be reduced to a simple question of economics. The costs of modifying the environment must be weighed against additional returns from the system in terms of product produced per unit of time. At one end of the spectrum is the natural environment with no control by man, and the other extreme is complete control of all factors in enclosed tanks. Unfortunately, the research data required to select the appropriate degree of control for a given species are not available in most cases.

An alternative source of valuable information in making plans for long-term aquacultural development is the successful practices used for animal husbandry of similar domestic species. The extent to which environmental control is economically profitable with domestic animals at present should provide guidelines for predicting which types of farming will be most successful with new species. This information was used in the following paragraphs concerning environmental factors of major significance.

Temperature is a particularly important factor with poikilothermic animals since their metabolic rates change drastically with ambient temperature. At high temperatures within an animal's normal range, feeding rates, and growth are much more rapid than at lower temperatures. In some tropical areas temperature fluctuations are slight so that optimum conditions for extensive culture of certain species exist throughout the year. In areas where greater fluctuations occur, the periods of optimum temperatures are shorter, and greater value can be derived from control of temperature to permit year-round use of facilities. A good example of intensive aquaculture of a carnivorous cold-blooded animal is trout for which relatively rigid temperature control is usually exercised. Herbivores such as mussels and milkfish are, on the other hand, farmed extensively with no control of temperature.

Water quality is a critical factor in an aquatic organism's environment because of the continuous exchange of gases and other substances through the organism's gills. With extensive practices the maintenance of water quality is left to natural processes such as decomposition, photosynthesis, bacterial action, and exchange of gases with the atmosphere. The biomass of an organism supported in a body of water is limited by the rate of removal of metabolites and the exchange of oxygen by these natural processes. Supplemental water treatment practices are used to speed these processes or remove wastes to an increasing extent with more intensive culture systems. Control of water quality in intensive systems is accomplished by exchanging water, circulating or aerating the water, and removing particulate matter or debris physically. Other possible means of control are those commonly used in the treatment of industrial or domestic wastewater including sedimentation, physical and chemical filtration, air stripping, biological filtration, and chemical treatment. Each process for removal of undesirable wastes involves additional costs. In most cases sufficient data are not available to predict the economic benefits of water quality control on a commercial scale.

Farmers have generally been unsuccessful in attempts to rear livestock in the presence of their natural predators and competitors. Even in ranching operations predators are usually eliminated. Based on this experience aquaculturists will probably have to control predators to some extent in any type of system. Potential predators include insects, crustaceans, fish, reptiles, and mammals (including man), and the control of such a variety of animals over large areas of water required for extensive operations is practically impossible. In intensive systems involving smaller areas and less water volume, control of predators and competitors is possible. Experimental shrimp culture in seminatural bodies of water in the United States has been characterized by great variation in survival rates. The instances of poor survival are probably due to predation although no thorough studies of the causes of these mortalities have been made. It is likely that the farmer's inability to control predators in large natural bodies of water will be a major hindrance to development of profitable extensive practices.

The control of competing species is important because their presence can cause considerable loss of efficiency through undesirable competition for food, oxygen, and space. In natural or seminatural culture systems the control of undesirable species poses a major problem. An advantage of intensive systems is their suitability for the control of competing species.

Although some plant growth in a culture system is normally beneficial, excessive growth may interfere with harvesting, or may be harmful when large quantities (either vascular or algal plants) decompose and create oxygen deficiencies. Plant growth is often excessive when nutrient levels have been increased by feeding or fertilizing. Control can be accomplished in small, intensive systems, but most methods, including chemical applications, are not practical in large systems.

DISEASE

Disease problems are encountered less frequently in extensive culture systems than in intensive systems. Crowding and feeding prepared diets contribute to disease problems.

Treatment for disease is usually accomplished by one of the following three methods: removal of animals from the water for treatment, changing the water quality to kill parasites, or chemical treatment through feed additives. None of these can be done economically in an extensive system. Similarly, prophylactic measures can be taken in intensive systems but are not feasible for extensive culture.

DENSITY

An important biological factor frequently ignored in planning a culture operation is the behavior of the animal under crowded conditions. Territorial or aggressive behavior may make a species undesirable for use in intensive systems. Freshwater shrimp and many crabs are examples of animals that exhibit behavior which makes them unsuitable for high density culture.

Yields of species from any system vary over a wide range depending on the densities that can be supported. Densities range from an upper limit determined by the behavior of the animal downward in relation to the degree of environmental control exercised and the amount of food supplied. With most domestic animals, we have bred varieties better suited to life in crowded conditions, i.e. we have changed the animal's behavior through selection. Aquatic animals can undoubtedly be bred selectively, as well, to increase their tolerance to crowding so that species presently being considered only for extensive culture may be used in intensive systems.

GENETICS

Successful animal husbandry today is dependent on improved breeds of animals; varieties which have been selectively bred for survival and growth in captivity. With a few aquatic species such as carp and trout selective breeding for strains suited for intensive culture has been accomplished. However, the stocks of most species being used experimentally for aquaculture are wild rather than domestic varieties. While wild strains can be expected to do well under seminatural conditions, the potential for growth and survival in intensive systems cannot be evaluated adequately with wild varieties. The potential benefits to be derived from domestication of wild species are clear when we compare wild and domestic varieties of geese, ducks, or hogs. The ability of most wild aquatic species to utilize an intensive culture environment and compounded foods can probably be improved significantly through selective breeding.

Economic Aspects

Nearly all considerations in the evaluation of a commercial operation are ultimately expressed in economic terms. However, for purposes of this discussion some aspects of only four topics — facility costs, competing uses of environment, operational costs, and dependability — will be examined. Applicable data for most individual situations are lacking so research must be planned from general information at hand.

FACILITY COSTS

The direct costs of a facility are generally much less for extensive culture than for intensive culture even though the area required is much less for an intensive system. The purchase of necessary equipment for even minor environmental control requires substantial capital. The cost of an extensive facility may, on the other hand, be low if natural waters can be obtained free or leased at a low rate. Many countries are willing to lease public waters for a small rental fee to encourage the development of new industry.

An exception exists when estuarine areas and adjacent land have a high value for other uses such as housing developments. In these cases coastal land may be a major cost, and it may be desirable to utilize less expensive land further from the water. The culturist is then forced to use some form of intensive culture.

COMPETING USES OF NATURAL WATERS

Even though a private company may be able to obtain possession of natural waters for extensive culture at low cost, this cost probably does not represent the actual economic loss to society incurred by the commitment of the waters to aquaculture. Actual economic losses would be imposed upon the following groups:

The commercial fishing industry, through loss of productive areas and possibly through the loss of larval animals produced elsewhere.

The recreational fishing and boating industry, if the area can no longer be used for recreational purposes.

Industries, municipalities, and private home owners, if the area had been used for waste disposal and can no longer be used for that purpose.

Industry, if culture activities interfere with water transportation.

In planning approaches to aquaculture the long-term projected uses of all resources involved must be examined carefully. The potential economic value of many coastal areas for housing and recreational uses in particular frequently overshadows the potential contribution from aquaculture. Multiple-use of many estuarine areas will certainly be necessary in heavily populated areas. For efficient use of research funds probable uses must be anticipated by administrators, and aquacultural research must be directed accordingly.

On the positive side, modifications of natural areas for extensive culture are neither expensive nor permanent. Since few if any irreversible changes are made for extensive culture, experimentation with extensive culture can be conducted for short periods in many situations without competition to other uses of the natural waters.

Private land for intensive culture is normally sold to the user willing to pay the highest price. For this reason problems of multiple-use and competition between various users do not arise as they do on public property.

OPERATIONAL COSTS

Because present knowledge of operational expenses is scanty, direct comparisons between operational costs of extensive and intensive culture practices cannot be made. The following list of activities will serve as a point of reference for comparing various types of culture operations:

Stocking — No major differences exist in stocking procedures.

Feeding — Costs of distributing feed are roughly proportional to the area under culture. Feed distribution costs per animal decrease as animal density increases. Feeding is not necessary in some extensive operations.

Environmental control — Mechanical aeration and temperature control cannot be used on an extensive basis for economic reasons, but can be used in intensive systems.

Water exchange and circulation may be accomplished by tidal action, water currents, or mechanical methods (costs of mechanical methods are related to area under cultivation).

Only limited predator or competitor control are possible in extensive operations, but complete control is possible in intensive operations.

Disease treatment and control — These are not possible in extensive systems.

Security — Costs of patrolling are directly related to size of the area.

Harvesting — Harvesting is considerably more expensive in natural waters than in man-made tanks or ponds.

RELIABILITY

The reliability of an aquaculture operation to produce expected results is extremely important from an economic point of view. Generally, the less subject the operation is to losses from natural phenomenon such as storms, drought, extreme temperature and floods, the more reliable the operation becomes. The environmental control required to free the operation from these risks is expensive.

Experimental aquaculture has been characterized by frequent failures. Through research the biological problems can be solved. Weather related problems, however, will persist regardless of man's skill as an aquaculturist. By definition extensive culture systems are more vulnerable to problems created by unfavorable weather.

Environmental Aspects

An aquaculture facility may either be affected by environmental modifications made for other purposes or it may cause environmental changes. Some of these changes should be considered in planning for aquaculture.

Housing developments adjacent to culture facilities may have a direct effect. Pollution of water supplies may be a a result of direct dumping into culture areas from domestic, industrial or agricultural sources. Spraying for purposes of insect control is another source of pollutants which must be considered. Diversion of natural fresh water supplies for power, irrigation, or other uses is a likelihood in many areas. These factors could each have pronounced effects on extensive culture operations as well as changing the quality of water sources used for intensive operations.

Other environmental modifications such as the construction of channels for shipping or the construction of storm protection levees can have similar adverse effects.

Intensive culture facilities are likely to cause pollution of the environment in the sense that their effluents are different than the natural water introduced into the systems. Experimentation is beginning with closed intensive systems that produce no effluent. Little if any pollution is likely from extensive systems unless animals are fed heavily or chemical control of predators is practiced.

The introduction of foreign species either purposely or inadvertently may cause ecological changes. Both the risk of introducing diseases to native animals and the risk of introducing exotic species are greater in extensive operations than in intensive culture systems. This is not a problem, however, if only native species are cultured.

Social Aspects

Social and political considerations cannot be ignored because they dictate the availability and distribution of money for research. In areas of high unemployment, practices requiring a large labor force may be encouraged as opposed to an automated operation. While the introduction of automated aquaculture into an area where none existed would provide employment, the replacement of traditional practices with automated procedures might reduce employment.

As man becomes more aware of the quality of his environment, aesthetic changes caused by aquaculture may be reasons for resistance to further development. Pollution in the form of odors or changes in water color may be objectionable. One example is the objection by home owners along the west coast of the United States to the placement of oyster culture rafts suspended in public waters near their homes. Another example is the legislation resulting from a sudden affection for marine mammals by the United States public. Sea otters are protected regardless of their damage to a valuable fishery product, abalone.

The many possible social factors affecting aquaculture are too numerous to discuss here. These problems are compounded when ownership of the culture area is uncertain or when public waters are used for culture.

Conclusions

Although the culture of each species in each location will require separate decisions concerning the appropriate degree of environmental control, general conclusions can be made based on information available at this time.

Legal problems involving extensive culture on public land will probably present major obstacles to this approach. While some improvement of this situation may occur, the development of intensive culture on privately owned land has clear advantages over extensive culture on public land.

Biologically the relative effectiveness of intensive and extensive approaches varies considerably, depending upon the species, its feeding habits, behavior, and environmental requirements. Our experience with other forms of animal husbandry suggests that with most species intensive approaches are more efficient than extensive approaches. Major differences noted between mammals or poultry raised in traditional animal husbandry and the fish and shellfish being considered for aquaculture with respect to food habits and the animals' ability to control body temperature are arguments in favor of intensive culture. Animals that may be raised successfully on an extensive basis are those herbivorous filter feeders which can utilize a wide variety of plant species as food.

Initial costs of a facility are higher with intensive culture while indirect costs to other users of the culture area are higher with extensive culture. Sufficient data are not available to make general comparisons of operational costs or of yield from a given investment.

An extensive culture system is highly subject to losses due to environmental changes. Regulation of effluents from a culture system may hamper either extensive or intensive operations unless the systems are closed with no effluent.

Social considerations are extremely complex and must be dealt with separately in individual situations. Indirect costs to other users of natural areas must not be ignored. Since the private aquaculturist does not always have to bear all these costs, his decision to conduct an extensive culture operation for personal gain may not be compatible with the resource manager's decision which must take into consideration all uses of natural waters. Even the resource manager may be biased by the opportunity for a short-term measurable product from the natural areas as opposed to the less tangible values of the area to present users.

The author's opinion is that, with a few exceptions, extensive aquaculture is not likely to be economically feasible. Furthermore, when all direct and indirect costs of extensive aquaculture are considered, the direction of research efforts toward the development of techniques for extensive culture does not appear to be warranted. On the basis of available knowledge and comparisons with modern animal husbandry the rearing of most omnivorous and carnivorous species will probably require the use of intensive culture techniques for economic gain.

Report on Technical Session III

1. As a basis for the intensification of fishery development programs, particularly in the developing countries, the Conference attempted to assess the short and long-term opportunities for increased production of conventional and nonconventional resources. It also identified the present constraints to the successful implementation of development programs and considered methods and approaches by which these might be overcome.

The Resources

2. It was estimated that the conventional, presently exploited resources, could yield a further 30 million tons annually of which up to 20 million tons could be drawn from coastal waters.

3. Incidental by catches and the effective utilization of fish, presently discarded or neglected could provide a further substantial tonnage.

4. It was noted that probably around 60% of these increased potentials could be found in tropical waters which were of particular interest to the developing countries.

Nonconventional resources could be placed in two categories. The first included such resources as the Antarctic krill (*Euphasia*) which might, in time become the world's major fishery product. Experimental harvesting had provided catches of up to 15 tons an hour. There was a need for improved harvesting techniques and, possibly, even, new types of vessels. If these problems could be overcome the ultimate yield might be of the order of 50 million tons annually.

5. The second category of nonconventional resources included such species as lantern fish, light fishes, small pelagic crabs, boar fishes, and squid. They also presented a harvesting problem which, if overcome would allow them to yield an additional 50 million tons annually.

6. Aquaculture operations now provide around 5 million tons annually of fish and crustacea. This, in time, could be increased 10-15-fold. Attention was drawn to the scope for such operations in the developing countries where there appeared to be over 2 million ha of suitable area. It was also noted that marine molluscs offered a considerable latent potential.

7. It was concluded that the picture for increased production, particularly in the tropical regions was generally encouraging and that the short-term effort should be directed at the more effective harvesting and utilization of the conventional resources.

Development Planning

8. It was emphasized by the Conference, that, to be fully effective, fisheries development programs should be preceded by careful planning studies directed at such aspects as market surveys, technical feasibility, and also socioeconomic factors. It was noted, however that in planning development programs full account should be taken of varying national and regional conditions and objectives. There were also differences between the developing countries themselves.

9. It was important that recipient countries of development aid programs should create the circumstances in which such programs could operate with a reasonable chance of successfully attaining the objectives.

10. In the above context it was also noted that many development projects failed to attain their objectives through a lack of timely and adequate follow-up action. It was concluded by the Conference that provision for review and follow-up action should be incorporated in all project work programs.

11. It was also concluded that, where appropriate, provision should be made whereby the private sector could subsequently operate effectively towards industry development and expansion.

12. It was, further, concluded that, where appropriate, and possible, a mechanism should be created whereby capital and technology could be provided at the planning stage to give impetus to industry development programs.

Development Programs

13. The Conference emphasized the continuing importance of the artisanal fisheries in the developing countries, all of whom identified it as a high priority sector. It was important both in terms of the contribution it made to the food supplies of the countries concerned, and because of the need to provide continuing employment and an improved standard of living to the communities concerned.

14. It was, however, recognized that it presented many complex and challenging problems to development authorities which would have to be overcome before its full potential could be realized.

15. One such problem was the dispersed nature of the artisanal fishing communities. It was thought that as a matter of policy effort should be made to centralize landing areas for artisanal fishermen thus allowing an improved range of services to be provided in the fields of collection, distribution and marketing of fishermen's catches as well as social services. Such measures would serve as a basis for the upgrading of these small scale fisheries and facilitate their transition to larger scale operations.

16. A further constraint, identified by the Conference, was the lack of appropriate social structures. The Cooperative system had, in some cases proved useful but was often difficult to organize and suffered generally from a lack of managerial and commercial expertise. It was suggested that a new approach would be for Cooperative Societies to operate as small scale industry development corporations.

17. It was also suggested that one of the major problems, that of providing efficient methods of collecting and distributing fishermen's catches might be overcome through the use of larger fishing vessels to serve as mobile landing centres.

18. It was recognized that the development of artisanal fisheries might be helped by the concurrent operation of

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heavily capitalized industry working alongside. This could result in higher returns through better marketing arrangements and heavier concentration on available resources.

19. It was stressed that, in common with other development activities, artisanal programs must be preceded by detailed inventories of physical and human assets to provide the framework for the selection of the appropriate objectives of such projects and the methods of implementing them.

20. With regard to the conduct of development programs concerned with larger scale fisheries there was general agreement that training facilities and programs had to be strengthened if the developing countries were to expand their fishing industries on a significant scale. There was, particularly, an acute shortage of technologists in the fields of processing, marketing and distribution and, indeed, in all sectors of industry.

21. It was suggested that Governments in developing countries should strengthen their establishment of technologists.

22. It was also suggested that fisheries institutes and organizations in the developed countries should consider arrangements whereby they could offer training facilities and advice on all matters concerning fishery development to fisheries agencies in developing countries.

23. It was suggested that considerable impetus would be given to fishery industry development programs in the developing countries through mobilizing the skills and experience available within the well established industries of the developed countries.

24. It was noted that no effective machinery existed at present whereby this reservoir of assistance could be brought into operation.

25. It was recommended that the administrators of aid programs in the developed countries, in consultation with FAO, should explore ways and means of achieving a greater participation of industry in the planning and conduct of development programs.

Financial Assistance

26. Adequate financial assistance and credit facilities are essential if progress is to be made in all sectors of fishery industry development.

27. At the level of artisanal fisheries progress has often been delayed because of the reliance of the fishermen on traders and financiers. Various methods of overcoming this were referred to, including the introduction of funding arrangements which would provide low interest rates and more flexible collateral.

28. There was a need for banking institutions and other funding authorities to adopt a more flexible policy with regard to financing both large and small scale fishery development programs. Reference was made to one country where loans to small scale fishermen were based on the proven merit of the recipients rather than on the collateral they could provide. This had proved successful and might be usefully adopted on a wider scale.

FAO Technical Conference on
Fishery Management and Development

TECHNICAL SESSION IV – SECTION 1

Regional and Other Case Studies — Southeast Pacific

CHAIRMAN: J. F. CARRANZA

Stock Assessment of the Peruvian Anchovy (*Engraulis ringens*) and Management of the Fishery[1]

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The upwelling of cool nutrient-rich water makes the area off Peru one of the most productive in the world. The first major use of this resource was the production of guano. In 1957 the fishery for anchoveta (*Engraulis ringens*) for reduction to meal and oil began on a significant scale. Catches rocketed to 8 million tons by 1964, making Peru the country with the biggest catch of fish. Most of the production (averaging some 2 millions tons of meal) is exported, and fish meal is (with copper) one of the two biggest earners of foreign exchange in the Peruvian economy.

Scientific studies of the resource, including collection of detailed statistical data of the fishery, have been carried out from an early stage. Research has been facilitated by the setting up of the Instituto del Mar del Peru, with the assistance of UNDP and FAO. Studies of the population dynamics of anchoveta have shown that by 1965 the stock was being heavily exploited, and that under average conditions the sustainable yield was around 8–10 million tons, being higher when the bird population is low.

Regulations to manage and conserve the stock include a closed season in the middle of the year when catches are low, and at the beginning of the year when small fish are abundant, and a limit to the total catch during a fishing season (September–August). However, regulations have not prevented development of great excess capacity in vessels and processing plants.

During 1972 there was a severe crisis in the fishery, when there were unusual oceanographic conditions and an almost complete recruitment failure. Catches in the second half of the year had to be cut to nearly nothing. Hopefully the stock is now rebuilding, but these events emphasize the need to reduce the excess capacity, so as to improve the economic status of the industry and stability of the stock.

Les remontées froides des profondeurs ("upwelling"), riches en éléments nutritifs, font des eaux péruviennes l'une des plus poissonneuses du monde. L'exploitation du guano a été la première utilisation industrielle de cette ressource. La pêche à l'"anchoveta", ou anchois péruvien (*Engraulis ringens*), pour transformation en farine et en huile de poisson, a commencé d'être pratiquée sur une échelle importante en 1957. En 1964, les captures avaient fait un saut à 8 millions de tonnes, mettant le Pérou au premier rang de la pêche mondiale. La majeure partie de la production de farine de poisson (2 millions de tonnes en moyenne, environ) est exportée: avec le cuivre, c'est devenu la principale source de devises pour l'économie péruvienne.

Dès ses débuts, cette pêche a commencé d'être étudiée scientifiquement, donnant lieu à la collecte de données statistiques détaillées. La recherche a été facilitée par la création de l'Instituto del Mar del Perú, entreprise avec l'assistance du PNUD et de la FAO, dont les études sur la dynamique des populations d'anchois ont montré, en 1965, que les stocks étaient intensivement exploités et que, en moyenne, le chiffre de production que l'on pouvait soutenir en permanence était de l'ordre de 8 à 10 millions de tonnes, quitte à l'augmenter lorsque la population d'oiseaux de mer diminue.

Une réglementation a été instituée pour exploiter et conserver les stocks: notamment, la fermeture de la pêche au milieu de l'année, quand les captures sont faibles, et au début quand les poissons de petite taille sont abondants; en outre une limite du tonnage total est imposée pendant la saison de pêche (septembre à août). Mais, cette réglementation n'a pas empêché que se développe une capacité excessive, à la fois des bateaux et des usines de traitement.

En 1972, la pêche a traversé une période de crise aiguë, par suite de conditions océanographiques anormales et de l'échec à peu près total du recrutement de jeunes, les prises du second semestre ont été réduites à

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un tonnage insignifiant. Heureusement, le stock est en train de se reconstituer, mais cette crise aura mis en lumière la nécessité de réduire la capacité excessive d'exploitation, de manière à améliorer la situation économique de l'industrie comme la stabilité du stock.

El afloramiento de aguas frías y nutritivas hace que la zona situada enfrente del Perú sea uno de los lugares más productivos del mundo. El primer empleo importante de estos recursos fue para la producción de guano. En 1957 se inició en gran escala la pesca de la anchoveta (*Engraulis ringens*) para su transformación en harina y aceite. Las capturas ascendieron a ocho millones de toneladas para 1964 por lo que el Perú pasó a ser el mayor país pesquero. La mayor parte de la producción de harina (que promedia unos dos milliones de toneladas) se exporta y es (con el cobre) uno de los dos capítulos que aportan más divisas a la economía del país.

Los estudios cieníficos de los recursos, entre los que figuran la recopilación de datos estadísticos detallados de la pesca, se efectúan desde las primeras fases de ésta. Las investigaciones se han visto ayudadas por la fundación del Instituto del Mar del Perú, con ayuda del PNUD y la FAO. Los estudios de la dinámica de las poblaciones de anchoveta indican que para 1965 habían sido muy explotadas y que, en condiciones normales, el rendimiento sostenido giraba en torno a 8-10 millones de toneladas, siendo superior cuando la población de aves era escasa.

Se han dictado normas para regular y conservar las poblaciones. Entre ellas figuran la veda, a mediados de año cuando se pesca poco y al principio del mismo cuando los peces de talla pequeña son abundantes, además de establecer un límite total de capturas durante la temporada de pesca (septiembre–agosto). No obstante, estas normas no han evitado un enorme exceso de capacidad de barcos y fabricas.

Durante 1972 las pesquerías atravesaron una seria crisis debido a condiciones oceanográficas adversas y a una falta casi total de nuevos reclutas. En la segunda mitad del año las capturas tuvieron que reducirse a casi nada. Afortunadamente las poblaciones están ahora recuperándose, pero lo anteriormente sucedido pone de relieve la necesidad de suprimir exceso de capacidad con objeto de mejorar la situación económica de la industria y la estabilidad de las poblaciones.

THE richness of the fish resources of the Peruvian sea area has been known for a long time, and man has used the coastal resources for his subsistence since pre-Incan times. Industrial use of the productivity of the huge anchoveta resource started in the nineteenth century with commercial exploitation of the large guano deposits. These are the droppings of fish-eating sea birds, which had accumulated on the nesting sites on the rocks and islands along the coast over hundreds of years, to layers 50 m thick in some places. Between 1848 and 1875 20 million tons of guano were exported to Europe and the USA to be used as fertilizer, and most of the accumulated deposits were depleted by the end of the century. Harvesting of the guano was carried out without any regard for the need of maintenance and protection of the bird colonies, and their population and annual guano production were at a low level when the Government's Compañía Administradora de Guano was established in 1909. Measures taken by the Company included protection of the bird colonies, with the result that their population and the annual harvest of guano gradually rose again.

Fishing was traditionally a small-boat operation carried out all along the coast by a substantial number of fishermen using a variety of gear. They have until recently provided the major part of the fish used for local consumption.

After attempts to start commercial fishing enterprises in the 1930s, the organized Peruvian fishing industry started to get off the ground with the increasing market for fish in the USA during World War II. This gave rise to a fishery for tuna, swordfish, and bonito, and to the establishment of processing factories. Fishmeal plants were installed to utilize the offal from the factories. These plants also started to process anchoveta, and some fishing for anchoveta for this purpose had already taken place in 1949.

The gradual resumption of fishing in the countries affected by the war after 1945 led to increased competition in the market for the Peruvian products, which halted development of the processing industry for fish for human consumption and caused the industry to look for new markets. The anchoveta fishmeal production continued to increase, to a level of 70,000 tons in 1953/54 and 250,000 tons in 1956. It was not until 1957, however, that the specialized and independent anchoveta fishmeal industry really started. At that time, the world demand for fish meal for use in the poultry and pig industries was increasing quickly, and important sources such as the Californian sardine fishery had declined seriously. Once started, the industry quickly developed, the catches increased in a spectacular way, and processing factories gradually appeared all along the Peruvian coast.

It is not surprising that development of the anchoveta fishery was seen as a threat to guano production, which had been managed so successfully by the Compañía Administradora de Guano. Heated discussion took place in the 1950s and early 1960s on the damage that the fishery might cause to the bird population, and requests for limitation of the fishery were heard. But none of this could stop the industry expanding. In this situation, the need was felt for much better knowledge on the magnitude and biology of the anchoveta resources.

For many years the Compañía Administradora de Guano had carried out a modest amount of research on the biology of the large seabird population, including some investigations on the anchoveta biology. Also, the Ministry of the Navy and the Fisheries Service (Pesca y Caza) of the Ministry of Agriculture carried out research along the Peruvian coast on hydrography and fisheries oceanography, respectively. Some coordination of this work was considered desirable, and as a result a Council of Hydrobiological Research (Consejo de Investigaciones Hydrobiológicas) was set up late in 1954. Once the anchoveta fishery started to develop rapidly, it became clear that the Council could not meet the research requirements needed, and it therefore decided to request a UNDP/FAO project to establish a marine fishery research institute. This project was started in 1960. The research institute (later named Instituto del Mar del Perù) was set up with sections dealing with biology, oceanography, technology, and economics. Emphasis was given to improvement of fishery statistics and study of the biology and dynamics of fish resources, in particular the anchoveta. The Institute soon developed into a major fishery laboratory. Thanks to the foresight of the Council, research data, in particular good detailed statistics on the catch, fishing effort, and length compositions, thus became available from a relatively early stage in the development of the industry onward. This greatly facilitated analysis of the effects of fishing, required some years later as a basis for management of the fishery.

In view of the great importance of the anchoveta fishery and the difficult problems that had to be resolved, the first UNDP/FAO project was succeeded by follow-up projects, concentrating on specialized advice and assistance to the Instituto del Mar. An important feature became the organization of special meetings of an international Panel of Experts, a small number of foreign specialists in fish stock assessment, meeting about once a year with Institute staff to review available information and to prepare joint reports on the state of the anchoveta stocks, management action needed, and further research requirements.

A considerable amount of data and knowledge on the biology and state of the anchoveta stocks has accumulated since the start in 1960.

The present paper summarizes and reviews the state of knowledge. Although the authors have been connected with this work for several years, it should be noted that most of the work and studies on which this paper is based have been carried out by the Institute staff, by some other foreign scientists, and by the anchoveta panels. Any mistakes in this paper are, however, the sole responsibility of the authors. Most of the original studies have been published in the various publication series of the Instituto del Mar.

Biology of the Anchoveta

The area of distribution of Peruvian anchoveta (*Engraulis ringens*) is practically restricted to the area of upwelling of cool, subsurface, nutrient-rich water along the coasts of northern Chile and Peru, and its main concentrations are found approximately between 5°S and 25°S Lat., although the species is encountered to 37°S. The upwelling is the cause of the extraordinarily high productivity of the area, and is related to the northward moving Humboldt (Peru) current and the offshore movement of surface water under the influence of wind and the earth's rotation. It is restricted to the coastal zone. Seasonal and annual fluctuations occur in the strength of the upwelling and width of the upwelling zone. The picture is further complicated by the occurrence of large eddies in the surface water, which may carry oceanic water back to the coast. The distribution and concentration of the anchoveta varies with fluctuations in upwelling, and usually it is found between the coast and 50 miles offshore, in the upper 60 m of water, and in temperatures between 14 and 21C. In addition to these normal variations, exceptional hydrographic conditions may occur – known as "El Niño" because they often appear around Christmas time – bringing warm tropical and oceanic water close to the coast, and the upwelling may disappear. This phenomenon, which often occurs with an interval of about 7 years, profoundly disturbs the ecological system. Primary production is greatly reduced; fish may die; anchoveta disappear from their usual grounds and may concentrate in the remaining favorable areas, or disperse; the guano birds leave their nests and migrate away or die. The effects on anchoveta mortality and recruitment are not well known, but the evidence does not suggest that the natural mortality of anchoveta of fishable size is seriously increased.

Meristic characters (gill rakers, gut length) suggest that the fish population in the southern area (south of 16°S Lat.) is more or less separate from those further north. This is supported by tagging experiments that showed rather long-range movements of fish in all directions both in the central-northern and the southern area, but little exchange between these areas. Fish of the southern group apparently extend into Chilean waters, as a substantial number tagged off south Peru were recaptured by the Chilean fishery. Therefore, the fishery in one of the two major areas will, under normal circumstances, have little effect on the fishery in the other, but it is possible that eggs and young fish from the south are carried northward and contribute to northern stocks.

The anchoveta is a relatively short-lived fish with a high annual mortality, and few fishes survive to over 3 years of age. They grow fast, reaching an average size of about 9 cm in 6 months, 12 cm in a year, 15 cm in 2 years, and few reach 20 cm in length. Since first maturity is at about 12 cm, a large number of 1-year-old fish participate in spawning. Spawning takes place throughout the area and at all times of the year, but there is little spawning between April and June and the major spawning period is in August–September, with a usually rather lower peak in January–February. Spawning in the southern area shows less distinctive peaks than in the north.

The anchoveta normally occur in dense shoals, which spread at night and concentrate again in early morning. There is some segregation into shoals of fish of different age and size, usually found in about the same areas although very small fish may be found close to shore. Young fish from the main (August–September) spawning begin to be recruited to the fishery in about January, at a size of 8–10 cm, and recruitment continues during the following months. In this period catches consist to a substantial proportion of these small fish ("peladilla"). Before and during the major spawning period (August–September) shoals are difficult to find and catches are usually low. In September–December the catches consist nearly entirely of adult fish.

The southern "stock" is normally much smaller than that in the central-northern area. The Peruvian catches in the south constitute roughly one-tenth of the total Peruvian catches, and Chilean catches fluctuate between one-twentieth and one-tenth of the total Peruvian catch.

The fishery is carried out by purse seine, with boats usually leaving during the night and returning after midday, although in recent years the number of trips of more than one day has been increasing. The shoals are spotted visually when they are at the surface, by looking for diving birds, or by echo-sounder when they are deeper. In recent years some companies have organized systematic searching with a number of boats to find the good concentrations of fish.

Development

Between 1955 and 1961 anchoveta catches increased at the almost incredible rate of doubling each year, as shown by the figures for total annual landings, in millions of metric tons:

1955	0.1	1961	4.6	1967	9.8
1956	0.2	1962	6.3	1968	10.3
1957	0.4	1963	6.4	1969	9.0
1958	0.7	1964	8.9	1970	12.3
1959	1.9	1965	7.2	1971	10.3
1960	3.3	1966	8.5	1972	4.5

Since 1964 the annual weight of fish caught by Peru has exceeded that caught by any other country.

This rapid expansion was helped by a number of technical advances such as early introduction of synthetic nets and powerblocks for handling larger nets, and by the ability of the world market to absorb the increased supply. Except for a temporary drop in 1960, the price received for meal remained constant, or even increased, during the development period. The period of expansion in catches came to an end as the limit of the biological potential was approached, and as the Government introduced controls to conserve the resource. Since 1964 total catches by fishing year (September–July) have fluctuated between 8 and 10 million tons.

Nearly all the meal and oil produced is exported. The fishing industry has thus become a major earner of foreign exchange, in some recent years passing copper as the biggest single item in Peru's total exports, and comprising over a quarter of its total. The development of fishing also stimulated a number of supporting activities (such as boat building), which means that the benefits of the development in fisheries were spread through much of the Peruvian economy. Although a number of foreign companies are engaged in the fishmeal business, the majority of companies are nationally owned, and the biggest company is Peruvian owned. Peru has been highly successful in developing its fishery. Since the mid 1960s the control of the exploitation of the large but finite anchovy resource for the best economic and social benefit has raised new and difficult problems, particularly in the need to know more about the resource and the effect of fishing on it.

Stock Assessment

A well-known effect of a growing fishery is that even though the total catch rises, the increase is not proportional to the fishing effort, and the catch per boat declines. At high levels of fishing, further increase in fishing effort does not lead to a higher total catch, and may even cause the catch to fall. Thus, one method of assessing the state of the fishery and the potential yield of the stocks is to analyze the relation between stock abundance and fishing effort or sustainable catch. Stock abundance is most easily measured as catch per unit effort, but this must be corrected for any changes in effectiveness of a nominal unit of effort. In Peru these changes have been marked because the size and efficiency of the average purse seiner has increased steadily as the fishery has developed.

TABLE 1. Fleet size, catch and effort of man and birds, and number of days fishing during the fishing season, in the period 1960–72.

Fishing season (Sept.–Aug.)	No. boats	Total tonnage of boats (in '000 GRT)	Total catch of the fishery (in million tons)	Nominal effort (in million GRT trips)	Size of bird population (in millions)	Estimated catch by birds (in million tons)	Total catch man+birds	Total estimated nominal effort man+birds	No. of days fishing during the season[a]
1960/61	697	37.4	3.9	7.3	12.6	2.0	5.9	11.0	299
1961/62	911	54.0	5.5	9.0	17.0	2.7	8.2	13.4	296
1962/63	1493	105.8	6.9	13.3	18.1	2.8	9.7	18.7	275
1963/64	1778	141.4	8.0	19.0	14.7	2.3	10.3	24.5	289
1964/65	1622	136.9	8.0	18.6	16.5	2.6	10.6	24.6	267
1965/66	1581	142.4	8.1	20.6	4.4	0.7	8.8	22.4	222
1966/67	1580	150.1	8.2	17.4	4.6	0.7	8.9	18.9	166
1967/68	1467	153.3	10.0	21.4	4.3	0.7	10.7	22.9	155
1968/69	1417	157.1	10.1	21.0	5.2	0.8	10.9	22.7	162
1969/70	1450	180.2	10.9	21.9	4.7	0.7	11.6	23.3	175
1970/71	1350	180.4	10.0	18.0	4.5	0.7	10.7	19.3	136
1971/72	1370	193.8	9.3	16.2	6.5	1.0	10.3	17.9	115

[a] Excluding the days when fishing was allowed in the south only.

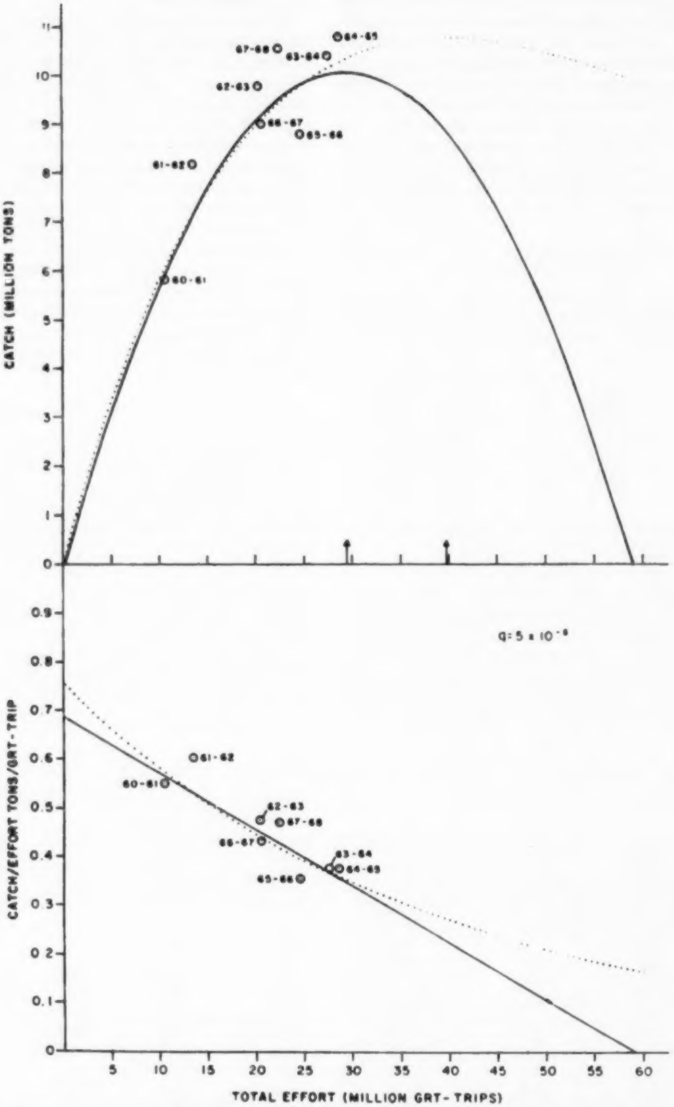

FIG. 1. Relation between total fishing effort of man plus birds, and catch per unit effort (below) and total catch (above), using the logistic (—) and the GENPROD model (. . .). From Schaefer 1970.

Within a given fishery season, the fishing effort of an individual vessel is approximately proportional to its size; therefore, as a first step toward standardization, the fishing effort was expressed as the number of fishing trips multiplied by the average GRT of the vessels actually fishing during the period. But an important problem was that not only the size of the vessels, but also their gear, fishing tactics, and their total fishing efficiency, increased, so that one trip in say, 1970, might have had a different effect in terms of fishing mortality to that of a trip by a vessel of the same size some years earlier.

Furthermore, the catch per unit effort does not depend only on abundance of the fish, but also on the density in the areas being fished; and this is affected by distribution and concentration of fish, which may vary from year to year. More important, as the stock declines, the density of local concentrations of fish, and hence the catches, may remain high. Thus, the decline in abundance will be underestimated, as will increase in effective fishing effort, which in turn will give too favorable a picture.

Most anchoveta assessments have consisted of analyses of catch and effort data. Some of the more important data for such analyses are given in Table 1. In the simplest form, a linear relation between total fishing effort and catch per unit of effort can be assumed (logistic model). This gave a fairly good fit to the available data, but the fit was improved by using nonlinear functions (e.g. an exponential relation or the GENPROD model (Pella and Tomlinson 1969)). A complication was caused by the guano bird population in the period 1961–65, at a level of about 17 million, eating an estimated 2.7 million tons of anchoveta annually, but after the 1965 El Niño this number was reduced to some 4 million birds, which ate an estimated 0.7 million tons of fish (Table 1). To allow the use of data from before and after 1965 together, the total catch by man plus birds was calculated, and the effort for this total was expressed in the number of fishing units that would have been needed to obtain this total catch. Some of the resulting curves, discussed by the first session of the Panel of Experts on Population Dynamics of Peruvian Anchovy (1970), are shown in Fig. 1. These and other curves indicate that the optimum yield of the stocks under average conditions is between 10 and 11 million tons (which, after subtraction of the amount at present eaten by the birds, leaves some 9 or 10 million tons for the fishery), and that the fishing effort since 1964 gave a catch close to this optimum. The extrapolated right-hand side of the curve is very different in the two models, the logistic one suggesting a steep fall in total catch at higher levels of effort, the GENPROD model (and also other models using nonlinear relations) showing a rather flat-topped curve. Consideration has been given to the effects of different estimates of the changes in efficiency that have taken place. These alter the details of the slope of the curves but do not alter the main conclusions on the value of the potential yield, and the present situation of the fishery.

Other methods for stock assessment exist, particularly more detailed models that consider inter alia the growth and mortality rates of individual fish. Whereas in general these models allow a much more detailed analysis, each method has its own specific problems and limitations, particularly the need for more specialized data, which are not always easily available. For example, these methods often require information on the age-composition of the catches, and unfortunately the age-determination of the anchoveta still presents difficulties. Other approaches to evaluate the situation in the fishery have been applied when possible. Estimates derived from the best data on age-composition, and from the number of fish caught from each year-class during its life span (cohort analysis), suggested high mortality and exploitation rates. Data from tagging experiments were, within their limitations, consistent with these findings. Surveys of the number of eggs in the sea could not be done frequently enough for reliable stock estimates, but a recent provisional analysis of such data as were available suggested a stock size of the same order of magnitude as estimated by the catch/effort analysis. Attempts have also been made to obtain quantitative estimates from echo-acoustic surveys. In short, all possible methods were applied.

The first assessment of the anchovy stock were made in 1965. Although later studies have made more detailed examinations of the population dynamics of the anchoveta, and have used a greater variety of methods of analysis and sources of data, increasing the reliance that can be placed on the assessments, they have not changed the basic conclusion that the anchoveta stock is heavily exploited and that further increases in the fishery will not give any significant increase in catch. The estimate of the potential yield for the fishery has been modified from 7.5 (Murphy 1967) or 8 (Boerema et al. 1965) million tons to 10 million tons (2nd Panel Report 1972), but much of this difference is a real change in the amount of fish eaten by the birds, the populations of which declined heavily as a result of the 1965 El Niño.

Despite the generally gratifying agreement between various assessments, some major doubts still remain. An important question is the degree, if any, by which the true effective effort (and the fishing mortality generated) has increased since 1965. Quotas and other regulations have maintained the catch per fishing year (September–August) within the range of 8–11 million tons. The nominal fishing effort to obtain these catches has not varied much, but there are indications that the fishing mortality has increased. This would support the hypothesis that the effectiveness of a nominal unit of effort has increased. The incorporation of a correction for such increased efficiency in the analyses produces a more flat-topped yield curve. The conclusion that the current effort would produce a sustained yield not significantly different from the maximum sustained yield is unchanged, but there is a greater likelihood that an appreciable decrease in effort would not significantly decrease the total yield, and might in fact increase it.

If the efficiency has increased, then the stock size is smaller than expected, and this could have serious consequences, especially by making the population unstable and less able to recover from transient unfavorable environmental conditions. For example, although under average conditions an adult stock of the present size is capable of producing as abundant a brood of recruits as larger stocks, this may not be the case when conditions for the survival of young fish are unfavorable. Also, if effort continues to increase, a moment must be reached where the resource will collapse. A study of the relation between the abundance of adult stocks and subsequent recruitment in the anchovy (as in many other stocks) deserves careful attention. Concern about the possible instability of the population and the likelihood that effective effort has increased led the Stock Assessment Panel, at the 1971 meeting, to advocate a reduction in effort as an important measure to assure long-term well-being of the industry.

One point should be stressed. Estimates of sustainable yield made in these studies refer to average conditions, but many factors, most importantly the amount of young fish recruited, vary from year to year. Recruitment variation will affect the level of annual allowable catch, and a catch quota regulation therefore requires adjustment to the magnitude of recruitment. Similarly, changes in distribution affect the desirable level of nominal effort. Until 1971 the recruitment variations were relatively small, the best observed year-class being about twice as strong as the poorest. Also, better and poorer year-classes alternated rather regularly. Since the quotas were established by fishing year (September–July), and the catch consisted of older fish in September–December and to a large extent of new recruits in January–June, and hence mainly of two year-classes, large adjustments to the total annual quota were not necessary. However, in years of exceptionally good or poor recruitment, adjustment is essential. The catch per unit effort figures, used hitherto for estimating recruitment, are subject to the effects of concentration of the fish, and cannot be considered as a good measure of abundance in a specific year, in particular when the environmental conditions are unusual. There is a need for the development of more reliable estimates of recruitment, to be measured at the earliest possible moment.

Management

By 1965 Peru was beginning to face the usual problems of a well-developed but unmanaged fishery – the need to ensure continued productivity of the resource, and the excess capacity of the industry – although through the Instituto del Mar, with the support of UNDP/FAO, it was fortunate in having better information on the resource than is often available. The excess capacity had arisen for the usual reason that the decision to build a new plant or new vessel was based on expected profitability (which was high), rather than its net contribution to the total catch or production of meal (which by 1965 was approaching zero). The same factors (high availability of fish, and good markets) that had ensured the successful development of the fishery now resulted in extreme over capacity and economic difficulties. By 1971 the fleet was so large that the allowable catch was taken in about 90 days fishing, while there were enough plants to process the whole world catch of species used for fishmeal if they had been run at full capacity. A fleet and a processing capacity of not more than half the present size would be sufficient to catch and process the 9–10 million tons of anchovy that the resource can produce, and savings in costs of $50 million upward could be achieved by eliminating the surplus capacity. This would also reduce the dangers of overexploitation of the resources.

The needs for management are therefore obvious, and a series of measures have been introduced by the Government from 1965.

These measures serve one or more of three purposes: to protect the small fish, to limit the total quantity caught (fishing mortality), and to reduce capacity (or total costs). Since anchovy are growing fast when they first enter the fishery at around 8-cm length, and the yield of meal and oil from a ton of small anchovy (peladilla) is less than from a ton of larger fish, the yield from a given brood of anchovy is increased by avoiding catching them until they are about 12 cm long. The selectivity of purse seines cannot easily be adjusted to avoid catching small fish, but two measures have been used to control the catches of peladilla. The peladilla are abundant at the beginning of the year, and since 1967 fishing has been stopped at this time, usually for 2 months. In addition, port captains have authority to stop landings at individual ports for a short period whenever the proportion of small fish is unduly high. These measures have undoubtedly increased the production of meal and oil.

A variety of measures has also been introduced to control the total amount of fishing. The earliest, established in 1965, were a closed season in the middle of the year when catches are normally light, and a total catch limit (quota). One effect of the quota was that companies started to build more and bigger boats to obtain a greater share of the total. Although older boats were gradually removed and the total number of boats decreased, the total capacity of the fleet continued to increase and the quota was reached in fewer and fewer fishing days (Table 2), even though on the basis of continuing assessments the quota was gradually increased. In order not to shorten the season too much, a 5-day working week was introduced in 1967. This also eased the pressure on the fishermen and factory workers, and had beneficial social effects – as important an objective of management as maximizing gross catch or net economic returns. As already mentioned, a closure at the beginning of the year was also introduced in 1967, principally to protect the peladilla. Minor exceptions, particularly as regards the fishery in the south of Peru, have existed to most of these regulations.

These measures have been successful in restricting the amount of fishing, but as a complete program of management they have biological and economic drawbacks. The quota has to be adjusted each year according to the strength of the incoming brood of fish, and measurement of the abundance of young fish before or soon after they enter the fishery is a difficult technical problem, not completely solved in Peru or anywhere else. Also, while the catches have been kept within the prescribed limits, it is not certain that these have been low enough to prevent a gradual increase in fishing mortality (the proportion of the total taken each year) leading to a smaller and probably less stable resource.

The economic problems are more serious. The regulations have not prevented a continuing increase in catching and processing capacity, so that the quota can be taken in fewer and fewer days. Some of the social effects of a continued closed season of several months have been mitigated by such measures as quotas for each month, which tend to spread the allowed fishing days over a longer period. Some first steps have been taken to reduce the capacity, such as the removal of the boats not fishing since the season 1969/70, and the obligation to remove one and one-half times the tonnage of old vessels if a new one is introduced. But these are not enough by far, and the fishery is much less profitable than it should be, even in a good to average year. This has made it difficult for the industry to surmount easily the problems when fishing is bad. This was clearly shown in 1972.

Occurrences in 1972

Developments in 1972 gave an unexpectedly early confirmation of the relevance of the stock assessment panel's conclusions concerning the instability of the stock. The first indication of an unusual occurrence in the anchoveta stocks was the scarcity of young fish being recruited to the fishery, observed by the Instituto del Mar during a survey in January–February 1972, and this low level of recruitment was confirmed from the commercial catches when the fishery started after the closed season in January–February. At the same time, there was increasing evidence of unusual oceanographic conditions. Direct observations in 1971 did not indicate any abnormality, but an unusual occurrence of a tropical crab (*Euphilax*) in the second half of this year was noted along the coast, and the percentage of adult female anchovies that were in spawning condition in August–October was lower than usual.

Early in 1972 the Institute noted an intrusion of warm, tropical water in the offshore area in the extreme north off the Peruvian coast, which thereafter penetrated further southward and developed into a full-scale El Niño. During the rest of the year the temperature of the surface waters off Peru have been several degrees above normal, though the abnormality has been less pronounced and less persistent in the south.

So far as adult fish are concerned, the unusual environmental conditions seem to have no direct harmful effect. However, the warm water concentrated the fish in local areas of cooler water, and the fish also tended to move south. These concentrations gave rise to extremely good catches of adult fish in March and April, but thereafter catches declined steadily, reaching a low level by the end of June.

More serious was the drop in recruitment. As already mentioned, a failure of recruitment was detected as early as January 1972, and the actual level of recruitment on the basis of catch and effort data was estimated in July 1972 to be only one-seventh of normal. Later evidence suggests that even this figure was optimistic. The precise reasons for the failure are not known. The adult stock in September 1971 was not unusually low, and because of the strong 1969/70 year-class was probably better than in some previous years. However, because of the unusually low fecundity of individual females, total egg production was low. If survival of eggs or young fish was reduced by an unfavorable environment, or by competition or predation by high concentrations of adult fish, this would have led to the observed poor recruitment.

A poor recruitment requires that catch quotas be reduced if the stock is to be harvested at its optimum rate. Thus it was pointed out by the Institute, as soon as the recruitment failure was apparent, that reduction in catches might have to be made, and in April it was recommended that fishing should be suspended. When the Expert Panel met in early July it confirmed the Institute's conclusions on the poor recruitment. It also concluded from the decline in the catches between March and June, from the magnitude of the total catch obtained in this period of over 4 million tons, and from the observation that no concentrations of anchoveta had been reported outside the fishing areas (neither further offshore, nor in deeper water, nor further south along the Chilean coast), that most of the adult fish, concentrated by El Niño, had been fished away. Because of a combination of these two factors, the stock was estimated to be at a dangerously low level. The Panel therefore recommended, subject to review in the light of later information, that no fishing should take place until a reasonably good recruitment had brought the stock on the way to recovery. Any fishing that occurred before recovery had taken place would increase the danger of a total collapse of the stocks, and of long-lasting effects on the fishery. In view of the fact, however, that more adult fish might have survived than the Panel estimated (because of dispersion or otherwise) and that additional late recruitment might be possible, it also recommended that regular surveys should be held to follow the developments and to evaluate the possibility of an earlier opening of the fishery.

The Institute organized monthly cruises, the so-called EUREKA cruises, in the period from July to October with a large number (up to 36) of commercial vessels, simultaneously surveying different sections along the whole coast by echo-sounder, and eventually fishing, during 1–3 days. The vessels also collected oceanographic data and plankton samples.

The cruises confirmed the low abundance in the whole northern and central region, although some shoals appeared in the later months in localized areas. In the south, where the recruitment failure had been much less pronounced and hydrographic conditions returned to about normal, shoals started to appear in September, and concentrations of about normal magnitude were found in October. Samples from the fish showed that in all areas spawning started early and that the percentage of spawning females was high. Egg density data obtained from the plankton samples confirmed the picture provided by the echo-surveys, that the total stock in the central–northern area was perhaps not more than 1/10 of normal, but that the amount of fish in the south was not much below normal. Estimates of total egg production together with information on egg production per female suggested a total stock size of only some few million tons, compared to a stock size in previous years of perhaps 15 million tons. Due to the low total stock size, egg production was lower than ever before, well below that of 1971 (which was itself low).

Catches obtained during the cruises showed that in all areas the remaining stock consisted mainly of large fish, of 15 cm and over, which demonstrated that the decline in the catches from April to June was partly due to dispersion of the fish and that larger fish had not been reduced to such a great extent as the Panel had estimated. On the other hand, it would seem that fish of 11–14 cm born in 1971 were even less abundant than estimated.

Because the cruises generally confirmed the Panel's estimates of total abundance, the Institute recommended that in order to safeguard as far as possible a stock for future spawning, the fish should not be caught until it appeared clearly that the 1972 spawning had resulted in good recruitment and recovery of the stock. If recruitment were again poor, no fishing should take place until the next spawning period. The Institute also stressed that even in October the catches continued to contain a substantial percentage of maturing and ripe fish, suggesting a second spawning during the season by many fish.

The appearance of the good concentrations of fish in the south, however, gave rise to the question whether fishing could be started in this area in which the fish form a relatively separate stock from those in the north, and where the situation was not every different from normal. The Institute considered that because southern stock now constituted a large part of the total stock, it might contain part of the central–northern stock migrated south as an effect of El Nino, and because fish in this area might contribute to repopulation of the areas further north by migration or drift of eggs and larvae, the fishery along the whole coast should remain closed.

However, the Ministry decided to open the fishery on November 20 in the southern area for boats that normally fished in this region, with the request to the Instituto del Mar to follow developments and report on results as a basis for further decisions. The catches were reasonably good, and confirmed earlier findings on shoal density, size composition, and maturity. A 2-week fishing experiment with some hundreds of boats was also planned for the central and northern region, from December 4 to 16, but most of the ports closed after one or two days, due to a high percentage of spawning females in the catches in some ports, and of very small fish, originating from the spawning some months earlier, in other ports. Concentrations of adult fish were encountered only in some localized areas.

Thereafter it was decided that the fishery in the central and northern area would remain closed at least until March. In view of the relatively small total catch in the south, some 40,000 tons per week, the fact that the neighboring Chilean fishery continued without limitation, and the appearance of young recruits along several parts of the coast and not merely in the south, the fishery in this latter area was allowed to continue.

The fishery in 1973 depends critically on the magnitude of the recruitment. Special EUREKA and research vessel cruises are planned for January and February to obtain the first estimates of this. Whereas the appearance of young fish in December is a hopeful sign, some apprehension is caused by the renewed appearance of warm water in the northern area. If recruitment is good, fishing could start again, although it is unlikely that the 1973 catch would reach the normal level, even without restrictions, due to the near-absence of the 1972 recruited fish.

The absence of fish and closure of the fishery have caused great hardship for the fishermen and everybody concerned in the fishing industry. There has been a continued conflict between the short-term interests of catching as much fish as possible at the present time and the long-term interests of assuring the future of the fish stocks and the industry it supports. This has led to close day-to-day contacts between the Instituto del Mar and those at the Ministry of Fisheries responsible for imposing regulations. These ensured that while there would be no delay in reopening fishing as soon as this might be scientifically justifiable, at the same time no undue risks would be taken with the future of the resource.

Once the hard but undoubtedly correct decision had been taken to restrict fishing during the second half of 1972 and at least into the beginning of 1973, the need arose for assistance to fishermen and the industry. Fishermen and factory workers have been virtually unemployed since June 1972, and those in central and northern Peru cannot expect to be employed again at least until March 1973. The fishing companies are having a correspondingly long gap in their income, and both employers and employees must be facing severe difficulties, even though the companies are better equipped to overcome these than the individual worker. The Government has therefore taken steps to alleviate economic distress by providing regular small-scale payments to individual fishermen, repayable after fishing recommences, and by making long-term loans to Peruvian fishing companies.

The Future

It is hoped that the fish stocks will soon return to normal following the strict measures taken in 1972, but this will not end the problems of the anchoveta fishery. A number of difficult biological, economic, and social questions remain to be answered before the fishery can be managed to provide the greatest continuing and assured benefit to the people of Peru.

The first questions concern the biology of the resource. The events of 1971–72 have shown that, in common with other stocks of similar shoaling pelagic fish, the Peruvian anchovy can undergo sudden and unforeseen changes. Though so far the decline has not been so severe or prolonged as that observed in the Hokkaido herring, the California sardine, or the Atlanto-Scandian herring, these examples of stocks that have reached virtual commercial extinction show how important it is to have a better knowledge of the general factors governing the abundance of pelagic fish stocks. In particular, more understanding is needed on the relative effects of changes in the physical environment, and in the abundance or density of adults, on the numbers of young fish entering the fishery. This is a major continuing task of the Instituto del Mar, although the history of the stocks mentioned above, which are all in waters adjacent to long-established high-quality research laboratories, shows that this task will not be an easy one.

In the social and economic field an early priority should be determination of the specific long-term objectives of future management policies. An objective might be to harvest and process the anchovy at minimum possible cost. A second objective must be to determine the use to be made of the large difference that should exist between the costs of producing fish meal and the world market price (should it, for example, all be absorbed in the central Government revenue). However, minimum costs are likely to coincide with minimum employment, and given social conditions in Peru, rather higher employment might well be desirable even if the costs were somewhat higher. Also, there are measures such as the current closure for 2 days a week, which have beneficial social effects, even though they reduce efficiency slightly, and which should be retained or introduced.

Whatever the long-term objectives chosen, these will imply big changes from the present situation — almost certainly the closure of many processing plants, the withdrawal of many vessels from anchovy fishing, and a reduction in the number of men currently employed. This could be a difficult process, and the transitional period will need careful planning, particularly to minimize the social disturbances. An obvious way of easing the problem is to divert vessels and fishermen to other types of fishing, which also fits in well with the Government's general policy of expanding the food-fish industry (hopefully repeating the successes of the anchovy fishery while avoiding its mistakes). Another method would be to use license fees or taxes on the remaining participants in the fishery (whose net income should improve) to pay compensation to those displaced, or to subsidize their resettlement in other occupations. In fact, the present crisis has enabled the Government to make a start with a substantial reduction in boats and plants.

Many of the decisions on long-term objectives and methods of overcoming transitional difficulties involve questions of national policy and priorities. However, these decisions need to be taken by the Peruvian Government on the basis of the best available technical advice on the immediate and long-term effects of alternative measures.

In this FAO is providing assistance and, as in the biological assessment, a major item in this assistance is the advice given by a panel of international experts, which met in June 1971 and again in April 1973.

Peru: A Case Study in the Establishment of a Food Fish Industry for a Developing Country[1]

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Based on Peruvian experience, the author describes the progress made over the past two years in establishing the food fish industry. Reference is made to the initial approach of the Government in setting up a separate Ministry of Fisheries while consideration is given to the influential and paradoxical situation of the Peruvian anchoveta industry. The role and the relation of the Government and the private sector are examined. The approach to various aspects of the food fish industry is commented on as the progress in developing the catching effort, the infrastructure, the training activities, the fish inspection service, the processing facilities, the commercial system, and the consumer education program is analyzed. Methods of funding, function of the multilateral and bilateral agencies, policy toward fishing cooperatives and artisanal fishermen, and place of the foreign factory trawler, are examined. Future opportunities are briefly discussed. An attempt is made to illustrate the necessities, problems, possible approaches, and opportunities of the food fish industry in a developing country.

Compte tenue de l'expérience acquise au Pérou, l'auteur décrit les progrès réalisés au cours des deux dernières années dans la création d'industries de produits de la pêche destinés à l'alimentation humaine. Les points suivants sont traités: décision initiale du Gouvernement de créer un Ministère des pêches; incidences et paradoxes de l'industrie péruvienne de l'anchoveta; rôle et connexité du Gouvernement et du secteur privé; solution de divers problèmes de l'industrie des produits de la pêche comestibles; développement de l'effort de pêche, infrastructure, activités de formation, réseau commercial et programme d'éducation des consommateurs; méthodes de financement, rôle de l'assistance multilatérale et bilatérale, politique concernant les coopératives de pêcheurs et la pêche artisanale, importance des chalutiers-usines étrangers; perspectives d'avenir. Enfin, l'auteur fournit quelques exemples pour illustrer les besoins, les problèmes, les solutions possibles et les débouchés de l'industrie des poissons comestibles dans un pays en voie de développement.

Basándose en la experiencia peruana, el autor describe los progresos realizados en los dos últimos años en la institución de industrias elaboradoras de pescado para la alimentación. Se hace mención del método inicial del Gobierno al instituir un Ministerio de Pesquería independiente y de la influyente y paradójica situación de la industria de la anchoveta. Se examinan el papel que desempeña el Gobierno y sus relaciones con el sector privado. Se comentan los diversos aspectos de la industria elaboradora de pescado para la alimentación, en relación con los progresos realizados en la pesca, la infraestructura, la capacitación, el servicio de inspección del pescado, los medios de elaboración, el sistema comercial, y se analiza el programa de educación del consumidor. Se examinan los métodos de financiación, el funcionamiento de los organismos multilaterales y bilaterales, las políticas encaminadas a las cooperativas de pesca y pescadores artesanos y el lugar de los arrastreros-fábrica extranjeros. Se trata brevemente de las futuras oportunidades. Se procura ilustrar las necesidades, problemas, posibles métodos y oportunidades de la industria elaboradora de pescado para la alimentación en los países en desarrollo.

THERE is no established formula by which food fish industries can be established in developing countries, although many basic criteria are common to all.

Much depends on such considerations as the funds available, the political and social climate, the historical association with fishing, local attitudes and aptitudes, and the need for protein and foreign exchange.

Above all, the whole structure must depend on the fishery resource and an accurate knowledge of it, how best it can be managed and how best it can be exploited.

Ideally, with no pressures, it would be preferable to spread such development over many years but this is rarely possible.

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The Peruvian Fishing Industry

The overwhelming segment of the Peruvian fishing industry is the anchoveta fishery that provides over 98% of the total Peruvian catch and represents the largest single species catch in the world, averaging about 10 million tons annually. The Peruvian fishery is essentially coastal, the greater part of the catch being taken within 80 km of shoreline along much of the southern and central coasts. The most important areas are Chimbote and Callao-Pisco. The anchoveta fleet consists of some 1500 purse seiners. The average size of these vessels has been increasing steadily from the original small wooden boats of 30–50 tons, now replaced by steel vessels of more than 350 GRT.

In addition to the anchoveta industry there is a trawler fleet of some 60 vessels for demersal species, including hake, and a bonito fishing fleet of some 80 seiners. Both fleets consist largely of converted anchoveta vessels, based mainly at Paita. Skipjack and yellowfin tuna fishing, yielding about 16,000 tons per annum, is carried out by foreign vessels operating under contract, and by a few local boats. Over 3000 smaller craft are engaged in traditional fishing for a variety of species, including crustaceans and molluscs. The overall food fish catch from the sea has remained relatively stable in recent years, between 180,000 and 200,000 tons per annum. About half of this total is represented by bonito, tuna, and other large pelagic species and smaller pelagic fish such as herring and mackerel. Hake and other demersal species account for some 80,000 tons annually.

Freshwater fisheries, yielding between 30,000 and 80,000 tons annually, are exploited by some hundreds of small craft and thousands of canoes, mostly on the Amazon River and Lake Titicaca.

Over 120 plants along the Peruvian coast convert the anchoveta catch into fish meal and oil, making Peru the major producer of fish meal with an annual output of around 2 million tons – some 45% of the world's supply. Of the other fish, the bonito are either canned, mainly for export, or consumed fresh or chilled, while the greater part of the tuna catch is frozen whole for export. Domestic supplies of fish are provided mainly by the coastal fisheries and demersal trawling. The freshwater catch is also consumed locally. Although domestic consumption is only 2% of the total catch, this amounts to more than 10 kg per head, which is relatively high by both regional and international standards.

ANCHOVETA

The explosive development of the Peruvian anchoveta industry is one of the most remarkable of postwar phenomena in fisheries. From a modest producer for local consumption, Peru has quickly risen to become the biggest producer of fish in the world. High initial profits combined with an enormous resource and an excellent market resulted in the prompt and large-scale injection of capital and technology, creating an industry that now earns more than $300 million (US) annually in foreign exchange. The export of fish meal and other fishery products is Peru's main foreign exchange earner, providing 38% of such earnings in 1971.

The extensive processing infrastructure and ancillary activities created through the rapid growth of the industry have provided much employment, especially in areas where work opportunities were previously limited. Fisheries development has also led to the establishment of associated industries such as shipbuilding, net and gear factories, and mechanical workshops.

It is important to appreciate the unique situation in Peru that allowed the Government to take vigorous action to establish the food fish industry on a bigger scale. This situation included such factors as a fishery-oriented economy, a substantial cash flow, a measure of technical competence, a resource capable of great exploitation, the desire for additional foreign earnings, and the need to provide more animal protein in the diet of the people. Thus, there existed a remarkable development climate and opportunity.

Paradoxically, the sheer size and importance of the present-day anchoveta industry has made it difficult to appreciate the problems and value of the much smaller food fish industry.

GOVERNMENT ORGANIZATION

It was in these circumstances that fishery activities were divorced from agriculture in February 1970 and a separate Ministry of Fisheries was established – a significant and far-sighted policy step.

This Ministry, apart from establishing an organizational structure covering all aspects of the industry, took over the Instituto del Mar and created the parastatal bodies of Empresa Pública de Servicios Pesqueros (EPSEP) and Empresa Pública de Comercialización de Harina y Aceite de Pescado (EPCHAP). In principle, the Ministry was to carry out the planning and EPSEP, the State Food Fish Company, to execute the plans. The objective of EPSEP at this stage was to give the State a participation in the food fish industry whereby influence could be brought to bear on pricing and distribution policies, infrastructure developed, and assistance given to the cooperatives. EPSEP could also represent the State in any fishery enterprise in which there was Government participation and involvement with both the local and foreign private sectors.

The concept of a State Food Fish Company operating in tandem with the private sector is interesting whether viewed as the thin end of the wedge in nationalization or as having a stimulating effect on the private sector by example or competition. Whatever the view, such a state enterprise can be the vehicle for activities that may be unattractive to the private sector (e.g. establishing a sales and distribution organization in the mountain region) or inappropriate for the private sector (e.g. providing coastal fishing terminals or inland fish markets). Naturally, these kinds of activities may require subsidies, particularly during the start-up period, but such a policy can be justified on social grounds.

One of the immediate acts of the Ministry was to develop a Five-Year Plan (1971–76) within the framework of the National Plan. While it is easy to criticize plans, they provide a focus for national effort even if they become a mixture of hopes, aspirations, and bids to secure an outsize share of the national economy. Such plans, if reviewed regularly and realistically, provide the necessary guidance for the action required.

Obviously, the first questions concern the size of the resource available and how it can best be exploited. Peru was fortunate in having an Instituto del Mar with 10 years of experience. However, practically all their budget and talent, supported by multilateral and bilateral assistance, had been dedicated to exploitation of the anchoveta resource, not to the food fish sector. There is a danger at the early stage of overoptimism on the part of Government officials and some time may elapse before realistic targets emerge. Peruvian officials have made plans on the basis of a sustainable annual food fish catch of 600,000 tons maximum and 400,000 tons minimum, compared to a present harvest of around 200,000 tons. There is time for further research or investigation in the light of experience to establish realistic targets but the main danger to avoid is that of allowing infrastructure and vessel development and investment to outstrip the real resource base. At this stage, too, the danger of utilizing hastily compiled data that might throw up convenient answers must be constantly borne in mind.

METHODS OF FUNDING

In any country the method of funding fishery development needs early consideration. The availability of such funds needs to be seen in relation to the overall economy. From then on, the administration of funds is a matter of policy decision. Apart from traditional private banking sources, a Fishery Division of the Industrial Bank has been created in Peru, which provides funds to both the public and private sectors. It is interesting to note that EPSEP has a role in recovering advances made to the fishery cooperatives, as it contracts to buy the catch and deducts from the proceeds the repayment due for the new vessels being built for the cooperatives. Eventually, this Division might acquire sufficient funds to become the Fisheries Development Bank.

Another source of finance developing in Peru is the Corporación Financiera de Desarrollo (COFIDE), the State Investment Corporation. COFIDE finances prefeasibility and feasibility studies, and loans money on terms varying from those obtained from international and foreign sources by taking an equity position in companies. This type of financial involvement is already in evidence in Peruana de Pesca S.A. (PERPESCA), a company having COFIDE as the major shareholder, with the Industrial Bank, EPSEP, and a private Peruvian fishing company as the other shareholders. PERPESCA will operate a five-vessel international tuna fishing fleet.

In looking at local funding arrangements it is perhaps relevant to consider the philosophy behind borrowing money from overseas. The fact that money is available is not sufficient reason to borrow it. It is all too easy to incur such a debt, doubly unfortunate if it means obtaining unsuitable or uneconomical equipment. Too frequently, tied loans only benefit the lender. It is also of practical value to relate the expertise of the lender to the funding. Many food fish industries have foundered almost before starting because of inappropriate funding arrangements, although today there is little trouble in obtaining good funding for well-conceived and realistic projects.

The question of the foreign investor is a vexing one. His capital, technical expertise, and international experience make his participation in a developing food fish industry desirable but there has to be a critical examination of his motives. Quite rightly, his prime interest is the welfare of his shareholders, and he is not usually motivated by any patriotic or pioneering spirit. He wants a reasonable return on his capital (higher than he would get in his own country because of the risk factor) and often seeks products, sales commissions, management fees, and tax benefits. He may be utilizing locked-in funds or taking an opportunity to expand. Although there are many solid companies of high reputation and proven performance, it must be remembered that fishing operations, particularly new ones, attract the promoter and the speculator. But, of course, the latter category can sometimes serve a purpose in identifying an opportunity and making a start.

Peru is attempting to develop a food fish industry of coexistence but, even if the parastatal bodies, the Peruvian private sector, and the foreign investor develop together, there must be problems of conflicting interests, different management philosophies, and diverse aims and considerations. Although difficult, such problems are by no means irreconcilable.

In funding, the role of multilateral and bilateral assistance needs to be examined. Too often assistance is pressed on a developing country in the hope of securing influence or equipment orders, and in such cases the well-being of the recipient government or the ultimate usefulness or result of the project is the least consideration. Similarly, hurriedly conceived requests by governments for assistance frequently result in duplication, competition, and misuse of money and talent. There is a great need for well-prepared and coordinated assistance programs, but all those concerned must appreciate that expertise of a satisfactory level cannot be turned off and on like a tap. Both recipient and donor need to exercise tolerance and develop understanding if they are to obtain the full benefits of an assistance program.

Over the past 2 years a significant program of bilateral and multilateral aid has been developed for the Peruvian food fish industry, which should materially assist the implementation of plans. Two years is, of course, a short time for any government in any country to set up organizations, develop policies and plans, and to commence the physical process of implementing them. Both political and social considerations warranted speedy action in Peru and inevitably some lessons will be learned the hard way. If a perfect study was made of every problem, it is doubtful if there could be any progress. To hurry matters along, the Ministry has made extensive use of outside consultants; if there is a lesson to be learned from this, it is that their terms of reference need to be well defined. There is always a risk that such experts and consultants will work over the data of others and come up with a more handsome report than the previous one. But, with well-defined terms of reference, foreign experts can speed up implementation and make a substantial practical contribution to progress, albeit often at a high cost.

INFRASTRUCTURE

The Ministry started with a 3-year program to construct 16 fish terminals and 12 inland fish distribution depots. This program, which will be almost finished by the end of 1972, has developed some of the infrastructure necessary to service the artisanal fishermen and the fishery cooperatives, and to establish a sales network in the Sierra to improve the protein content of the local diet. The coastal terminals include simple processing facilities, refrigerated storage space, and ice-making plants. Some have quay space, others beach haul-out equipment. The inland distribution depots sell to local wholesalers and retailers. These depots have storage space for frozen and other processed fish, processing space, vehicle parking lots, and office accommodation for sales staff.

This $3 million (US) program may seem to be a relatively simple exercise but, by the very location of the installations, it has involved a variety of civil engineering problems. With these solved, the problems of training the human resources arise. These are perhaps the most difficult because there is no background or tradition to this type of activity. (The writer, incidentally, encountered similar problems in developing a national network of sales and distribution depots in the United Kingdom in the fifties.)

In developing these coastal terminals the Ministry has acknowledged the important role the artisanal fishermen and the fishery cooperatives can play in fishery development. It is easy – but wrong – to dismiss the artisanal fisherman as a person who contributes little to the economy. In a coastal fishery such as Peru's the artisanal fishermen and the fishery cooperatives are seen to be a most economic fishing unit if the yardstick of dividing expenses (including depreciation and interest on investment) by total catch is used. By providing the infrastructure and encouraging the cooperatives to build new vessels (about forty 50-ft vessels will have been completed in 1972, with a further 80 contemplated for 1973 and another 100 for 1974), the Ministry is fulfilling a social obligation as well as meeting an economic need.

In respect of small vessel design and construction, a sustained effort is needed to develop standard designs. This calls for realization that badly designed vessels remain a liability for many years. Furthermore, it must be recognized that the building of food fish vessels is a specialist business and not one that can be readily developed despite years of experience obtained with anchoveta vessels. A promising program has been initiated whereby surplus purse seiners from the anchoveta fleet are being converted to food fishing. There is probably a surplus capacity of some 500 vessels in the anchoveta fleet but because of age, size, condition, or lack of power, perhaps only 50 can be considered for this program. To purchase and convert such a vessel to a 30-ton capacity food fish boat with a 5–7-year life expectancy costs about $70,000 (US), an economic figure that is very attractive to owners whose fleet has either excessive capacity or a low written-down value.

UPGRADING QUALITY

There can be little doubt that the major problem faced in developing the food fish industry of Peru is to upgrade the quality of the product. As in many developing countries, fish has not hitherto been gutted or bled nor has it been stowed in ice. The increasing availability of ice is a big step forward but it takes a revolution to change the fishing habits of centuries. The growth of processing plants to provide products for sophisticated export markets will help establish an understanding of quality requirements. Similarly, it is hoped that the domestic market will develop a taste for good fish. However, the only way in which the fisherman will learn to handle his catch better is if it can be demonstrated that fish of good quality will give him a better return on a continuing basis than fish of poor quality. If, for example, the fisherman is to bleed, gut, ice, and box fish at sea, he needs and deserves to be paid for his extra work and for the reduction in catch due to lost fishing time, but unless fish of good quality can be landed, all the trappings of a modern food fish industry are largely a waste of time.

To improve quality and standards the Ministry has established the mechanics of a fish inspection service that deals with fresh fish at the coast and inland, processed fish, fish for export, and processing plants. The establishment of such a service in a country having a 2000 km coastline is a tremendous task, and will take several years before it can be made truly effective. Nevertheless, a start has been made at a few major areas of activity, e.g. the new terminal at Callao and the new Lima Wholesale Fish Market. Training courses are given that concentrate on practical aspects of fish inspection. At the same time an effort is being made to improve handling and establish better internal quality control procedures in the processing plants. This in-plant training has made a good start. Here, again, Peru had an advantage in having an established fish meal inspection service, the Empresa Pública de Certificaciones Pesqueras del Perú (CERPER) that, with the exception of plant inspection, handles the food fish inspection service. However, convenient as it is to have the organizational support of CERPER, the necessity to develop a new approach has become evident — not the least problem being to avoid the fish inspection service becoming branded as a police force.

Now that the effort is being made to catch and land more fish, hopefully in an improved condition, the next stage is to examine the fate of that fish. Until the improved infrastructure and domestic distribution facilities, backed by consumer education programs, take effect, there will be wastage (originally estimated as high as 25%) and an unequal distribution of supplies as the coastal populations are more accessible. These defects can be remedied slowly. In this respect it is encouraging to note the increasing sale of frozen hake in the Sierra cities and towns — fish delivered by Hercules aircraft in 18-ton parcels. This method of delivery is proving to be more economical than road transport.

FISH PROCESSING

Peru is fortunate in having a hake resource estimated at 100,000–300,000 tons annual sustainable yield. At present the catch exceeds 20,000 tons, which is converted into fish meal. A processing industry is to be based on this resource. Essentially export-oriented, the concentration will be on frozen fillet products, although salting and drying processes are being developed. Detailed plans for a major processing complex at Paita capable of handling 50,000 tons per annum are being prepared. While it is not yet clear how the complex will be developed, seemingly, it would be logical for the Government to develop the infrastructure (e.g. the quays, discharging facilities, ice-making and storing installations, repair yards, and cold storage) and prepare an industrial park upon which the private sector can develop various processing factories. If this is the case the next step in rationalized planning would be to license the production capacity of the proposed factories and the supporting fleets so that the resource is not overexploited and investment is maximized.

The Peruvian fish-canning industry flourished during the 1939–45 war but has diminished significantly in recent years, and much of the equipment is either outdated or operating in plants incapable of producing the high-quality products needed today. Improved supplies and reviving export markets are encouraging the more efficient of the companies to expand and, at the same time, a new EPSEP plant is contemplated for the canning of anchoveta as a food fish, but this development is still at the pilot plant level.

In this frozen food age, it is all too easy to forget the opportunities afforded by the earlier methods of fish processing, e.g. canning, salting, drying, and pickling. The emphasis is too often on more sophisticated products and it is well to ask what such sophistication achieves. In this respect, foreign advisers are inclined to rely on their own product experience rather than to attempt to determine the best process for the developing country concerned.

Apart from the traditional food fish resource, at least some of the 10 million ton anchoveta resource might be used and this, for food, presents a remarkable opportunity and challenge. In addition to canning, possibilities are being explored for freezing, drying, and salting the fish, and a food target of several thousand tons of anchoveta should be achievable within the next few years.

Distribution and Marketing

A profound change is under way in inland distribution and marketing. The Government provision of infrastructure, the EPSEP intervention in wholesaling and retailing (EPSEP operate over 100 retail selling points in Lima alone), the consumer education programs at all levels, the increasing price of meat coupled with a 15-day per month ban on beef selling, and the larger supplies of fish — all these combine to induce a far greater awareness of food fish.

A lot of money and effort are being devoted to this program. The increasing role of EPSEP and the apparent lack of return on private capital gives rise to the possibility of the State assuming all the responsibility for the domestic food fish market. EPSEP at present distributes only about 10% of the domestic-market fish so it would face an immense task in taking over the whole of the distribution. But in a country where fish are of such importance there is some merit in considering this suggestion, assuming that the physical and social problems can be overcome. However, if such a policy is enacted it will need to be carefully phased so that the fishermen and the consumers, the two groups who are meant to benefit the most, do so.

Training

In any country, the development of significant physical resources takes time, and then the problems of management and staffing begin. There is need for training in all fields at all levels. It is not possible to turn a somewhat archaic vocation into a modern industry of more than double the size without encountering serious manpower problems. However, training simply for the sake of training is not enough and there is a constant need to determine the human requirements. For example, a too ambitious fishermen's training centre in Peru could quickly lead to the oversupply of the market. Rather than a highly sophisticated training center, the development of training in the field by extension workers can be most effective.

Further, in respect of training, Perú is utilizing most beneficially the multiplicity of fellowships and study tours available from multilateral and bilateral sources. Efficiently organized study tours, tailored to the capacity and need of the participant, are proving to be a rapid way of giving authority to the decision-maker and experience to those who can speedily apply it.

Development Opportunities

As pointed out earlier, any development of the fishing industry is a slow process. For example, it might well take at least a year to identify a product opportunity, e.g. hake freezing, then a year to develop the feasibility of the project, and another year to do the detailed planning and seek out funds, after which it may take 2 more years to construct the factory — a total of at least 5 years. The current Peruvian approach to this problem is to license foreign factory trawlers to fish in Peruvian waters for limited periods for a fee or as a joint venture. Thus, an operation can be arranged in such a manner that much-needed fishing experience is gained, some training is acquired, Peruvian products are introduced to export markets, shipping opportunities are developed, additional fish is made available for the expanding domestic market, and foreign exchange is earned. While this is going on, shore-based installations can be built, perhaps even adjusted in the light of experience. There is, of course, the risk that the highly intensive fishing effort of large foreign trawlers could damage the resource but, if licensed prudently with a constant monitoring of the resource by the Instituto del Mar, overfishing can be avoided. Indeed, the experience gained should help to avoid overinvestment and overexpansion, and help guide the development of a shore-based program.

Little mention has been made of aquaculture. An active program, particularly for trout farming, is under development but significant results are a distance away. It is easy to become overenthusiastic and overoptimistic in planning fish culture without paying due consideration to the problems of disease, location, management, and markets.

The development of the Amazon Region is a major problem by itself. With a resource of, say, 30,000–80,000 tons, the food contribution locally is great and could be developed extensively. An initial but significant step forward is the provision of limited infrastructure in Iquitos. Further, the pilot scheme of EPSEP, whereby canoe fishermen are provided with ice, thus allowing them greater fishing time until refrigerated motor barges can collect their catches, can have far-reaching effects. There is a flourishing export trade in ornamental fishes and there is no reason why this luxury industry should not continue to grow Above all, the discovery of oil in the Amazon Region will change the whole economy of the area, bringing new opportunities to the fishing community.

In considering the future, it is interesting to conjecture about the opportunities opened up by the Andean Pact and other Regional developments. Peru is well placed to take advantage of such circumstances and, indeed, in some instances to take a firm initiative. Also, as the food fish industry develops, there will be a greater need for the inclusion of fish in trading agreements with other countries, e.g. in this way substantial exports can be developed for the big Japanese market.

The detailed planning stage has been reached on projects for the development of fishery complexes at La Puntilla, Samaco, and Meca Grande. These are to be substantial investments with full docking and processing facilities for shellfish, tuna freezing, and anchoveta. These installations are not likely to be in operation before 1976.

The role, if any, of Peru in the international fishing scene has yet to be defined although the joint company PERPESCA S.A. envisages a fleet of five 1000-ton tuna vessels to work in the international fisheries. In other fields, assuming economic criteria are used, any other major development, e.g. fishing the Atlantic, hardly seems likely or viable.

Constructive work is being achieved in Peru by those universities having fishery faculties but there is a need for coordination, otherwise there is the danger of work being done that is readily available elsewhere — at the price of a postage stamp! The same observation goes for work at technical centers and laboratories whose programs need to be slanted toward applying internationally-known techniques to the local problems and opportunities of Peru.

Overall, in looking at training programs, it must be remembered that the fishing industry is labor-intensive and, in many countries, it should probably be kept so. The best use, therefore, must be made of the human resources. This will be more and more the case as the food fishery activities of Peru move into the competitive climate of the international market place.

Even with an apparently favorable opportunity backed by an aggressive approach by the Government, it is evident that the development of any food fish industry is fraught with difficulties and problems. Nevertheless, the opportunities are there to be developed, even if there is no easy or quick way. Many lessons can be learned from the experiences and misfortunes of others. It is hoped that this paper has defined some of the guide lines, some of the problems, some of the ways to overcome them, and some of the opportunities.

Impacto de Medidas Regulatorias en la Industria Pesquera Peruana[1]

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VALDEZ-ZAMUDIO, F. 1973. Impacto de medidas regulatorias en la industria pesquera peruana. J. Fish. Res. Board Can. 30: 2242–2253.

El Perú posee un extenso litoral sobre el Pacífico de aproximadamente 2,300 km. Entre sus actividades más importantes se encuentra la pesca, basada en un 98% en el recurso anchoveta (*Engraulis ringens*). Las características de su mar son muy especiales debido a la acción de una corriente superficial de aguas frías conocida como la Corriente Peruana, en la cual existe un gran recurso hidrobiológico.

El principal recurso pesquero es la anchoveta, pez pelágico de pequeña talla y de gran reproductividad, que vive en aguas de la Corriente Peruana. Este recurso ha permitido que el Perú sea el primer país pesquero del mundo con una captura anual entre 9,5 y 12 millones de toneladas en los últimos años.

Los pronósticos para poder establecer un sistema conveniente de regulación, pueden basarse en los datos de crecimiento, reclutamiento y mortalidad, o en análisis de datos de captura y esfuerzo. El Perú con la cooperación de la FAO, ha convocado a cuatro reuniones de expertos internacionales de alto nivel. Tres de ellas para tratar sobre la dinámica de la población de la anchoveta, y una para estudiar los efectos económicos de las medidas de regulación.

En la reunión que estudió los efectos económicos de las regulaciones, se mencionó que la industria no era eficiente debido al exceso de capacidad de la flota y plantas y se anotó que mejoras en la tecnología y en el aspecto financiero debían acompañar la reducción de flota y plantas. Considerando como muy difícil la reducción voluntaria en cualquiera, se estimó necesario un elemento regulador obligatorio, mencionándose varios tipos de regulaciones. Los paneles sobre dinámica de la población de anchoveta también incluyeron en sus informes recomendaciones para la protección del recurso.

El Ministerio de Pesquería, que continuó la labor de la Ex-Dirección de Pesquería y Caza, ha dictado diversas regulaciones para proteger el stock. Regulaciones y controles se establecieron desde el año 1965, promulgándose para cada periodo anual.

El pescador peruano es el que más sufre las consecuencias de las paralizaciones en la pesca y trata de protegerse mediante el establecimiento de fondos especiales. El sector empresarial acepta y comprende las regulaciones pesqueras, prefiriendo que se dicten anticipadamente para poder planificar sus actividades.

Los científicos que recomiendan las regulaciones, consideran importante las vedas para la protección de los peces jóvenes, y como medida para reducir el esfuerzo de pesca. Básicamente, la regulación más general es la que establece dos meses de veda en verano y dos en invierno.

En el sector periférico la actividad que más ha sentido los efectos de las regulaciones, es la construcción de barcos. Con todo, también otras actividades menores, que dan ocupación a gran número de personas, tales como servicios de transporte, alimentación y talleres, han sufrido los efectos de las regulaciones.

Peru has a long shoreline — about 2,300 km — on the Pacific Ocean. Fishing is a major activity, based 98% on the anchoveta (*Engraulis ringens*). Conditions in the seas off the country are highly singular because of the effect of a cold surface current called the Peruvian Current, which harbors a major hydrobiological resource.

The principal fishery resource is the anchoveta, a small and prolific pelagic fish that lives in the waters of the Peruvian Current. This resource has made Peru the first-ranking fishing country in the world with an annual catch of 9.5–12 million tons in recent years.

Forecasts for the establishment of an adequate regulation system can be based on data for growth, recruitment and mortality or on analyses of catch and fishing effort data. In cooperation with FAO, Peru has called four meetings of high-level international experts, three of them to deal with the dynamics of the anchoveta population and one to study the economic effects of regulatory measures.

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[1] Preparado para la "Conferencia Técnica sobre Ordenacion y Desarrollos Pesqueros," de la Organización de las Naciones Unidas para la Agricultura y la Alimentación, celebrada en Vancouver, Columbia Británica, Canadá, del 13 al 23 de febrero de 1973.

Impreso en Canadá (J2938)

In the meeting to study the economic effects of regulations it was mentioned that the industry was not efficient because of the excess capacity of the fleet and plants ,and it was noted that any reduction in fleet or plant capacity should be accompanied by technological and financial improvements. Since any voluntary reduction was regarded as highly unlikely, it was felt that mandatory regulations were needed and various types of such regulations were mentioned.

The panels on the dynamics of the anchoveta population also included in their reports recommendations for protection of this resource.

The Ministry of Fisheries, which took over the functions of the former Dirección de Pesquería y Caza (Fisheries and Hunting Administration) has issued a variety of regulations to protect the stock. Regulations and controls have been established since 1965 and are issued for each annual period.

The Peruvian fisherman suffers the most from the consequences of interruptions of fishing operations and is trying to protect himself by setting up special funds. The entrepreneurial sector accepts and understands the fishery regulations and prefers that they be issued in advance so that it may make its operational plans accordingly.

The scientists who recommend regulation emphasize prohibitions for the protection of juvenile, spawning and larval fish, and as a means to reduce fishing effort. Basically, the most general regulation is the one that establishes two 2-month closed seasons, one in summer and one in winter.

In the secondary sector the greatest impact of regulation has been felt in shipbuilding. However, regulation has also affected other minor activities such as transportation and food maintenance services, which employ large numbers of people.

La Pérou possède une immense façade sur le Pacifique, d'une longueur d'environ 2,300 km. La pêche, qui repose à 98 % sur l'anchoveta (*Engraulis ringens*), représente l'une des plus importantes activités nationales. Les caractéristiques des eaux océaniques péruviennes sont très particulières en raison de la présence d'un courant superficiel d'eau froide, connu sous le nom de courant de Humboldt, et où existent de grandes ressources hydrobiologiques.

La principale ressource halieutique est constituée par l'anchoveta, petit poisson pélagique qui est doué d'une reproductivité élevée et vit dans les eaux du courant de Humboldt. Grâce à elle, le Pérou est le premier pays de pêche du monde avec des captures annuelles qui ont oscillé entre 9,5 et 12 millions de tonnes ces dernières années.

Les possibilités de mettre sur pied un système approprié de réglementation doivent tenir compte des données sur la croissance, le recrutment et la moralité ou des résultats de l'analyse des rapports captures/effort de pêche. En coopération avec la FAO, le Pérou a organisé quatre réunions d'experts internationaux éminents. Trois de ces réunions ont étudié la dynamique des populations d'anchoveta et une a examiné les incidences économiques des mesures de réglementation.

Durant la réunion consacrée aux répercussions économiques de la réglementation, on a déclaré que l'industrie n'était pas efficace en raison de la capacité excessive de la flottille et des usines, et l'on a fait valoir que des améliorations d'ordre technologique et financier devraient aller de pair avec une diminution des effectifs de la flottille et des usines. Comme une réduction volontaire est difficile à réaliser dans l'un et l'autre cas, on a jugé nécessaire la prise de mesures de réglementation obligatoires. Divers types de mesures ont été mentionnés à ce propos. Les réunions sur la dynamique des populations d'anchoveta ont également formulé, dans leurs rapports, des recommandations visant la protection des ressources.

Le Ministère des pêches, qui a succédé à la Direction de la pêche et de la chasse, a édicté divers règlements pour protéger le stock. Des mesures de réglementation et de contrôle, promulguées chaque année, sont appliquées depuis 1965.

Le pêcheur péruvien est celui qui pâtit le plus des limitations apportées à la pêche; il tente de se protéger par l'établissement de fonds spéciaux. Les chefs d'entreprises acceptent et comprennent les règlements halieutiques, mais désirent en être informés d'avance de manière à pouvoir planifier leurs activités.

Les scientifiques qui recommandent la réglementation jugent importantes les périodes de fermeture de la pêche pour protéger les stades juvéniles et pour réduire l'effort de pêche. Fondamentalement, la mesure la plus fréquente consiste à prévoir deux mois d'interdiction de la pêche en été et deux autres mois en hiver.

Dans le secteur périphérique, l'activité qui a ressenti le plus les effets de la réglementation est la construction navale. Ces répercussions affectent également d'autres activités secondaires qui occupent beaucoup de personnes, comme les services de transport, de ravitaillement et de réparation.

Generalidades

EL MAR PERUANO

EL litoral peruano es una excentricidad de la naturaleza; en efecto, a pesar de estar cerca de la línea ecuatorial, es un desierto en lugar de una jungla tropical. El agua del mar, a lo largo de casi todo el litoral, es fría (temperaturas entre 14 y 20 C) con salinidad promedio de 35°/₀₀. La temperatura ambiental es templada. La costa peruana sufre la acción de grandes corrientes oceánicas producidas por la rotación de la tierra, la fuerza de la gravedad y los vientos. La rotación de la tierra genera una gran elipse de aire denominada el "Anticiclón del Pacífico Sur" que sopla en dirección noreste a la altura del sur del Perú. Esta enorme masa de aire choca contra la Cordillera Occidental

de los Andes que tiene una altura media de 4,500 m, comenzando a desviarse hacia el oeste en su extremo norte.

Este viento desplaza las aguas superficiales y provoca movimientos de agua surgentes de las capas más profundas del fondo del mar, estableciendo un proceso dinámico, que renueva las aguas empobrecidas en sales minerales por la actividad de los vegetales clorofílicos, cambiándolas por aguas profundas que contienen una mayor proporción de nutrientes, lo que estimula a su vez la producción primaria a la base de la cadena alimenticia. De esta manera las sales minerales nutritivas no utilizadas pasan de las capas afótica y oligofótica a la capa eufótica, donde la suficiente luminosidad permite su utilización por los organismos vegetales. Esta constante acción de afloramiento en el mar peruano es la causa de su enorme potencial pesquero.

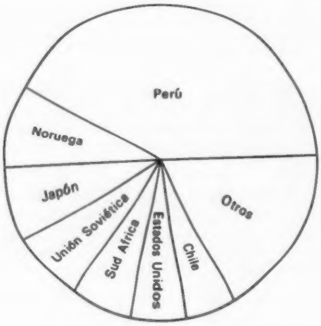
Se estima que este afloramiento se produce en un área de 850 millas a lo largo de la costa por 30 millas de ancho, aproximadamente 25,520 millas cuadradas (Zuta y Guillén 1970). Se presenta un afloramiento permanente entre los 14° y 16°S y otros entre los 4° y 8°S y 11° y 12°S.

Su profundidad varía de la superficie hasta los 100 m aproximadamente.

La Corriente Peruana

Hace cerca de 50 años (1923), Robert Cushman Murphy escribió que "La Corriente de Humboldt (hoy denominada Corriente Peruana), que fluye de sur a norte a lo largo de la costa occidental de Sudamérica, es directamente responsable por algunos notables fenómenos oceanográficos. También es la causante de la existencia en sus aguas de una vasta abundancia de organismos planctónicos de los cuales dependen recursos marinos insuperables. La uniformidad producida por los afloramientos a lo largo de la costa hace que sus aguas sean un medio ambiente constante y muy rico. No se puede hallar mejor ejemplo de una relación relativamente invariable entre organismos y medio ambiente."

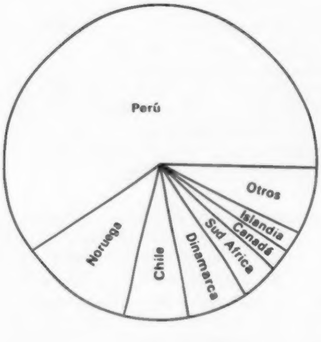
La denominada Corriente Peruana fluye a lo largo del litoral del Perú en dirección sur-norte, originándose en la Corriente del Pacífico Sur, entre los 40° y 42° de latitud



PRODUCCIONES MUNDIALES DE HARINA DE PESCADO 1971 (T.M.) Y SUS PORCENTAJES

Perú	1'934.5	41.89%
Noruega	408.4	8.84%
Japón	350.0	7.57%
Unión Soviética	350.0	7.57%
Sud Africa	272.6	5.90%
Estados Unidos	260.0	5.63%
Chile	213.0	4.61%
Otros	829.2	17.95%
	4'617.7	

CIFRAS PRELIMINARES



EXPORTACIONES MUNDIALES DE HARINA DE PESCADO 1971 (T.M.) Y SUS PORCENTAJES

Perú	1'750.7	60.00%
Noruega	338.4	11.50%
Chile	193.6	6.60%
Dinamarca	187.6	6.40%
Sud Africa	108.9	3.72%
Canadá	62.0	2.12%
Islandia	60.0	2.00%
Otros	221.9	7.59%
	2'923.1	

CIFRAS PRELIMINARES

(Popovic 1966). Se mezcla con las aguas de afloramiento entre los 30° y 29°S.

Por el norte choca con la Corriente Ecuatorial aproximadamente a los 5°S frente a la provincia de Paita. Este límite se puede desplazar más al sur dependiendo de las condiciones climáticas.

En el plano vertical se presenta desde la superficie hasta los 100–300 m de profundidad. Bajo sus aguas existe un sistema de corrientes que fluyen de norte a sur.

Su límite occidental estimado en base a mediciones de temperatura es de 150 a 250 millas extendiéndose más frente a la zona norte del litoral.

La Corriente Peruana transporta sus aguas a una velocidad de 0.2 a 0.3 nudos, hasta los 5° de latitud, aumentando de 0.5 a 0.7 nudos cuando se aleja de la costa. Según Wyrtki (1956) su desplazamiento es de 14 millones de m^3/seg. aproximadamente, siendo abril y setiembre los meses de mayor volumen.

Su productividad primaria no está aún bien determinada, variando de 0.2 a 4.0 gC/m^2 día. El índice de salinidad fluctúa entre 32 y $36^\circ/_{oo}$; la temperatura varia entre 14 y 25 C, de acuerdo a las estaciones.

El Recurso Anchoveta

La anchoveta (*Engraulis ringens*) es el principal recurso del mar peruano. Es un pez pelágico de pequeña talla, con un máximo de cerca de 20 cm, ovíparo, que puede reproducirse a 1 año de edad y cuya longevidad no parece pasar de los 3 años. La longitud total media a 1 año de edad es de 12 cm; antes de llegar a esa medida se le conoce como "peladilla." Su peso varía con el tamaño, los ejemplares de 12 cm teniendo como promedio un peso de 15 a 17 g. Puede soportar abruptos cambios de temperatura y salinidad, pero su medio normal son las aguas frías. Suele encontrarse a profundidades de 10 a 20 m pudiendo llegar hasta 80 m o más. La distribución vertical de la anchoveta es independiente de la profundidad del fondo.

El habitat normal de la anchoveta es un área del litoral de aproximadamente 80 km de ancho, pero en ocasiones se han encontrado ejemplares hasta mas de 180 millas de la costa. La anchoveta no es una especie migratoria, variando sus desplazamientos solamente entre el norte de Chile y la zona norte del Perú. Es posible que la población de la anchoveta peruana sea homogénea, aunque también hay importantes indicaciones de que podrían existir dos subpoblaciones: una en la zona central y norte del país, y otra en la zona sur que sería integrada con el recurso existente en la zona norte de Chile.

La anchoveta es una especie típicamente costera, cuyas concentraciones se presentan en mayor cantidad dentro de las 50 millas de la costa, con fluctuaciones estacionales La presencia de masas de agua de mayor temperatura durante el verano ocasiona la concentración del recurso en zonas costeras. Durante el invierno, se produce un fenómeno de dispersión a zonas alejadas de la costa, debido a la ampliación horizontal de aguas más frías, presentándose los cardúmenes hasta las 100 millas y en algunos casos hasta mas de las 180.

La anchoveta peruana alcanza su primera madurez sexual a los 12 cm de longitud total, aproximadamente al año de vida. Tiene durante el primer año un incremento medio de crecimiento superior a los 0.5 cm por mes en primavera y en verano, mientras sólo llega a la mitad de esta valor durante el otoño y el invierno. Este crecimiento se halla relacionado con la existencia de fitoplancton, que constituye el principal alimento de la anchoveta y que experimenta una baja considerable durante el otoño e invierno. La anchoveta se alimenta por lo menos tres veces cada 24 horas y la cantidad del alimento ingerido corresponde a alrededor del 5% de su peso total.

La anchoveta alcanza un tamaño de 8 a 9 cm a los seis meses de vida, 12 cm al cabo de 1 año y de 13 a 14 cm a los 2 años, pudiendo llegar a los 18 cm o más a los 3 años. La especie presenta dos períodos importantes de desove: uno en invierno y el otro en verano. Se ha encontrado una estrecha relación entre la madurez y el contenido en grasa de la especie, hasta el punto de distinguir el período de desove más intenso en coincidencia con el contenido mínimo de grasa en la anchoveta adulta.

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La magnitud de una clase recluta que ingresa cada año a la pesquería influye muy considerablemente en el rendimiento del recurso. Esto se debe a que la anchoveta es una especie de vida reducida — aproximadamente un máximo de 3 años — y por tanto, gran parte de los peces jóvenes que nacen durante 1 año constituyen un alto porcentaje de la población y son potencialmente los adultos desovantes de la próxima temporada. Se estima que el recurso de la pesquería de anchoveta está constituido en un 60% por la clase anual que ingresa a ella. En general, el recurso de la anchoveta peruana se sustenta principalmente de peces jóvenes entre 6 y 18 meses de edad.

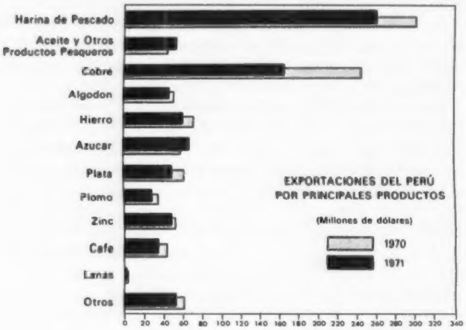
La magnitud de la clase entrante desempeña un rol decisivo en la captura y por tanto resulta importante adoptar medidas que permitan su conveniente explotación, con el objeto de mejorar su rendimiento, evitando la pesca cuando la mayor parte de los peces son muy jóvenes y por tanto de muy bajo rendimiento, que puede llegar hasta el 50% del rendimiento de un recurso adulto.

Datos Estadísticos

Se anexan los siguientes cuadros estadísticos sobre la producción pesquera e industrial del Perú: Distribución de las embarcaciones anchoveteras, años 1960–71; Desembarque mensual de anchoveta, años 1960–71; Captura mensual promedio, producción de harina, rendimiento y número de plantas, año 1971; Producción peruana de harina y aceite de pescado, años 1960–71; Producción y exportaciones mundiales de harina de pescado, año 1971; Exportaciones del Perú por principales productos, años 1970–71.

Consideraciónes Sobre Pronósticos a Corto Plazo

Para poder establecer la regulación de una pesquería, es indudablemente necesario hacer un pronóstico sobre



las posibilidades de explotación del recurso. Los pronósticos de largo alcance se agrupan alrededor del máximo rendimiento sostenido, fundándose en análisis de datos de captura, esfuerzo, crecimiento, mortalidad, etc. Los pronósticos de pequeño alcance consideran las variaciones a corto plazo en los parámetros de la población, siendo el elemento más importante el reclutamiento.

Durante los primeros años de una pesquería, estas variaciones tienen poca importancia, ya que el recurso soporta una pesca incipiente y las capturas gurdan una directa relación con el esfuerzo de pesca empleado. Posteriormente, a medida que la explotación se torna más intensa, los efectos en las capturas de los cambios en el reclutamiento son más acentuados. Cuando la población está altamente explotada y los rendimientos se encuentran en el máximo, el recurso es sumamente sensible a estas variaciones de corta duración.

Estas fluctuaciones causan problemas a la industria pesquera y pueden poner en peligro al recurso, sobre todo cuando existe un esfuerzo pesquero bastante alto como es el caso de la industria pesquera peruana, porque cuando se produce una reducción importante en el reclutamiento, la actividad pesquera para alcanzar la misma captura total es forzada a pescar una fracción mayor de la clase reclutada.

Entre las regulaciones a largo plazo está la de señalar un nivel de cuota anual de captura correspondiente a un reclutamiento medio que pueda ser alcanzado sin poner en peligro al recurso. Sin embargo, ésto significa que es posible desperdiciar parte del recurso durante los años en que las variaciones del reclutamiento sean favorables. Una solución es reajustar la cuota anual de acuerdo a los nuevos datos con que se cuenta sobre el reclutamiento en ese año.

Para establecer estos ajustes es necesario elaborar un programa de investigación que incluya diversos aspectos tales como observaciones del ambiente — sumamente importantes en la región del Pacífico sur-oriental por la forma en que los cambios ambientales afectan a los recursos pesqueros — observaciones acerca de reclutamiento, crecimiento, datos de desembarque, etc.

Reuniónes de Expertos

Comprendiendo el problema que significa el lograr un eficiente control del recurso anchoveta, el Gobierno peruano conjuntamente con la FAO ha convocado en cuatro oportunidades paneles de expertos internacionales y nacionales para estudiar los diversos factores que intervienen en la pesquería y hacer recomendaciones para un manejo racional de la pesquería.

PANEL DE JUNIO DE 1970

Este panel trató sobre los efectos económicos de las medidas reguladoras alternas en la pesquería de la anchoveta. Los objetivos establecidos que se desean alcanzar con las medidas regulatorias aplicadas a la pesquería de la anchoveta peruana son: (a) Asegurar que las capturas estén a nivel del máximo rendimiento sostenido o muy cerca de él; (b) Obtener una captura a un costo mínimo y utilizarla tratando de obtener el máximo provecho dentro del marco social, político y técnico-económico de la industria.

El panel tomó nota que la capacidad actual de las plantas excedía a la requerida para el procesamiento de la captura anual de aproximadamente 9,5 millones de toneladas. Trabajando las plantas durante 20 horas por día y 300 días al año con una capacidad media de procesar alrededor de 8000 toneladas por hora, podrían procesar 48 millones de toneladas de pescado. Si se desea procesar *solamente 9,5 millones de toneladas, la capacidad de las* plantas en igual lapso debería ser de solamente 1600 toneladas por hora.

Por otro lado con la capacidad de bodega de la flota en el año 1969, estimada en 212,000 toneladas repartidas en 1417 embarcaciones según se indica en el cuadro No. 1, se estableció que la flota con una captura por tonelada de capacidad de bodega y por viaje de 0,453 toneladas, debería operar 115 días pro embarcación para pescar 9,5 millones de toneladas en una temporada. Visto de otra perspectiva, la capacidad de la flota para capturar en 170 días los mismos 9,5 millones de toneladas debería ser de solamente 143,442 toneladas, lo que significaba una reducción de cerca de 32% de la flota.

Se estimó también que los costos eran excesivos porque parte de la industria es ineficiente, y porque hay un exceso de capacidad de flota y plantas, por lo que era necesario una restricción en las operaciones de la flota pesquera. Se sugería conveniente eliminar el exceso de la capacidad de flota con el objeto que un menor número de barcos pudiera operar con gran eficiencia durante todo el año, con la posible excepción de una veda de verano, lo que traería por consecuencia una sustancial reducción de la capacidad o número de plantas; la industria podría sin embargo operar todo el año. Se recomendaba que estas reducciones deberían tomar en consideración los barcos y plantas que tuvieran los mayores costos.

Se reconoció también que consideraciones sociales y de otra índole harían difícil promover estas reducciones en su forma más extrema, siendo particularmente difícil ser aceptada una temporada de diez meses con siete días de trabajo a la semana. Le eliminación del exceso de capacidad podría beneficiar a la economía peruana por lo menos con 30 millones de dólares al año y probablemente más. Una reducción sustantiva de la capacidad pesquera

CUADRO 1. Distribución de las embarcaciones anchoveteras.

	1960		1967		1968		1969		1971		
Eslora	No. de embarcac.	%	No. de embarcac.	%	No. de embarcac.	%	No. de embarcac.	%	No. de embarcac.	%	Capacidad de bodega ton. reg. net.
Menos de 49	249	34,0	5	–	2	0,1	2	0,1	1	–	45
50–54	113	15,5	15	1,0	4	0,3	1	0,1	1	–	60
55–59	114	15,6	33	2,1	19	1,3	11	0,3	3	–	231
60–64	222	30,4	233	15,1	184	12,5	152	10,7	102	7,0	10,572
65–69	17	2,3	759	48,0	701	47,8	650	45,9	557	38,0	64,075
70–74	–	–	139	8,8	127	8,7	124	8,0	109	7,2	15,848
75–79	11	1,5	98	6,2	94	6,4	97	6,0	88	6,0	13,937
80–84	5	0,7	195	12,4	205	13,9	233	16,4	249	17,0	45,727
85–89	–	–	3	–	3	0,2	5	0,4	6	–	1,278
90–94	–	–	30	1,9	48	3,3	85	6,0	102	7,0	26,016
95–109	–	–	–	–	–	–	32	2,3	99	6,4	27,656
110–119	–	–	–	–	–	–	–	–	32	2,2	11,119
120–124	–	–	–	–	–	–	–	–	105	7,0	36,583
Sin datos	–	–	65	4,1	80	5,5	25	1,7	19	1,3	4,560
Total	731	100,0	1,580	100,0	1,467	100,0	1,417	100,0	1,473	100,0	257,707

[a]No significativo.

e industrial reduciría grandemente la grave amenaza al stock de anchoveta proveniente de las dificultades económicas de parte de la industria, la que tiende a ejercer una fuerte presión en contra de las restricciones necesarias para proteger el recurso en dichas circunstancias.

También se hacía notar que mejoramientos tanto en la tecnología como en el aspecto financiero debían de acompañar la reducción de la excesiva capacidad de plantas y flota, obteniéndose de esa manera una mayor eficiencia económica. Aunque la reducción de la flota pesquera podría ser establecida fijando límites a la construcción de barcos que reemplacen a los obsoletos (por ejemplo exigiendo la reducción de dos toneladas de flota obsoleta por una tonelada de flota nueva) habría que considerar los efectos de esta política en la economía normal de la industria.

En general, se estimó que las dificultades de una reducción voluntaria de capacidad de planta eran prácticamente insuperables, y era necesario un elemento regulador obligatorio.

Uno de los sistemas reguladores que podría aplicarse a las plantas es establecer una cuota en el abastecimiento de la materia prima a cada una de ellas. Este sistema tiene la ventaja de incentivar a las plantas a utilizar con la máxima eficiencia la materia prima a un costo mínimo y a la vez les permitiría planificar sus operaciones. Entre las desventajas se mencionó el problema de determinar cada cuota y su periódica revisión; se necesitarían inspecciones diarias en los barcos y plantas y cabría la posibilidad de un estancamiento en la eficiencia de la industria al tener asegurada una cuota fija; los industriales tenderían además a proporcionar la capacidad de su planta y flota no tanto a la cuota fijada sino a las capacidades de la competencia, lo que podría tener como resultado que las plantas mantuvieran un exceso de barcos esperando un aumento en sus cuotas.

Un sistema alternativo podría ser el establecer cuotas de producción en las plantas. Tendría la ventaja de un control mucho más simple, pero en su contra está el posible desperdicio de la materia prima utilizada y menos control de la cantidad pescada.

Se sugirió que como posible solución para reducir la capacidad industrial podría establecerse un tributo en la industria con el objeto de adquirir el exceso de capacidad que sea necesario retirar, o sea alrededor de 2000 toneladas por hora de las actuales 8000. La reducción de 2000 toneladas horarias de capacidad podría significar aproximadamente 24 millones de dólares. En caso que el tributo se aplicara a la producción, se estimaría que podría ser de 12 dólares por tonelada para obtener la reducción deseada en 1año.

En cuanto a la forma de reducir la capacidad de la flota, se analizó el restringir la capacidad de la flota perteneciente a cualquier factoría proporcionalmente a la capacidad de su producción. Esto tiene la desventaja de un sistema demasiado rígido, que podría traer como consecuencia que unos puertos estuvieran sobrecargados y otros subcargados. También hay que admitir que la eficiencia de la industria se ve aumentada por la facilidad de que barcos de una fábrica descarguen en otras fábricas, cuando la primera no puede recibir materia prima. Otra desventaja es que no había forma conveniente de reducir la capacidad de la flota a corto plazo.

Un segundo sistema de control sería establecer cuotas de captura a una embarcación o grupos de embarcaciones. Tiene la ventaja de poder alcanzar el nivel deseado de captura sin otras regulaciones; las cuotas por grupos de barcos también permiten al dueño de tal grupo ajustar sus

CUADRO 2. Desembarque mensual de anchoveta (T.M.) 1960–71.

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Enero	310,799	460,577	448,878	822,025	1'130,190	1'121,190	1'495,273	1'598,033	1'551,445	1'341,434	1'083,799	131,852
Febrero	300,546	386,701	423,718	254,711	781,838	744,277	1'125,481	602,271	1'026,029	86,350	1'083,799	150,917
Marzo	291,195	294,195	470,228	681,047	1'098,029	1'120,212	1'236,490	929,643	846,698	1'897,414	1'090,412	2'578,086
Abril	187,075	380,253	570,094	751,094	810,153	840,175	1'071,377	1'262,657	1'192,380	1'319,905	2'030,141	1'573,131
Mayo	145,433	450,135	688,480	894,374	715,329	715,661	1'004,240	1'107,709	1'023,062	897,499	974,865	689,991
Junio	265,496	353,863	444,976	505,170	494,898	496,869	–	145,032	–	55,453	179,065	97,493
Julio	141,646	238,697	369,339	208,088	456,633	32,442	–	–	65,813	20,455	16,049	–
Agosto	128,016	196,547	286,819	198,327	301,322	–	–	–	88,458	1,142	–	–
Setiembre	169,400	222,626	353,900	258,915	257,151	80,840	690,082	261,744	1'348,827	486,032	1'335,174	1'205,203
Octubre	234,623	394,623	528,801	427,983	700,864	222,798	918,072	1'245,211	1'277,421	552,029	1'381,774	1'357,809
Noviembre	359,814	592,688	832,895	630,099	997,499	659,504	6,864	1'266,418	950,162	406,649	1'107,437	1'155,206
Diciembre	409,559	609,000	876,632	791,411	1'119,461	1'199,641	981,942	1'405,906	891,830	1'896,098	926,304	1'342,096
Totales	2'943,602	4'579,905	6'274,380	6'423,244	8'863,367	7'233,479	8'529,821	9'824,624	10'262,661	8'960,460	12'276,977	10'281,784

operaciones y su flota al sistema más eficiente y además permitiría a las fábricas una mejor planificación de sus actividades al contar con una cuota fija. Las desventajas de este sistema están determinadas por la dificultad de determinar la cuota de cada barco o grupo de barcos, ya que cualquiera de los sistemas que se aplicarían, sea tomando en cuenta las capturas anteriores o la capacidad del barco, son discutibles. Otro factor importante a considerar es que la licencia o cuota de pesca de una embarcacion tendría un alto valor comercial que podría ser negociado por el propietario.

También cabe considerar el establecer un impuesto a la producción que sirva para adquirir la sobrecapacidad de la flota pesquera. Se estimaba en 1970 que podría pagarse 200 dólares por tonelada, en barcos que fueran dados de baja. Otra posibilidad analizada fue la de transferir los barcos anchoveteros para la pesca de consumo humano directo, pero dada la enorme diferencia entre las capturas de anchoveta y otras especies, esta transferencia no tendría mayor significación en la solución del problema, por lo menos hasta que no se haya determinado con cierta precisión los recursos de otras especies.

Panel de Marzo de 1971

Esta reunión trató sobre la dinámica de la población de la anchoveta peruana.

Como antecedente cabe mencionar que durante el año 1970 se obtuvieron muy buenos rendimientos diarios en la captura de anchoveta. La captura total del año 1970 fue de 12'227,000 toneladas métricas de anchoveta y durante los meses de marzo, abril y mayo de 1971, los rendimientos habían sido extraordinarios, llegando algunos días a capturarse volúmenes del órden de los 160,000 toneladas métricas por día. Los promedios diarios de captura fueron en lo que iba del año 1971: marzo, 112,000 toneladas métricas; abril, 104,800 toneladas métricas; y mayo 111,236 toneladas métricas. El panel observó que a pesar de la cuota establecida, el nivel del esfuerzo pesquero en las últimas temporadas era más alto que lo necesario para obtener la captura máxima, trayendo como consecuencia que la abundancia del stock había disminuido y la inestabilidad del stock había aumentado.

Las propuestas que se hicieron para establecer las regulaciones para el año 1971 fueron: (a) En caso de que el reclutamiento fuera normal en el año pesquero 1970/1971, se debía de establecer una cuota de 10 millones de toneladas; (b) Si el reclutamiento no es muy diferente del normal, la captura en la parte restante de la temporada 1970/71 debería ser de cerca de 4,8 millones de toneladas, una vez que 5,2 millones de toneladas ya hubieran sido capturadas. Si por el contrario el reclutamiento es pobre, la cuota debería ser reducida en consecuencia; (c) Medidas adicionales a la cuota total propuestas por el Ministerio, como un límite de 20 días de pesca por mes, un límite de 1,2 millones de toneladas por mes, o un límite de cuatro días de pesca por semana, no cambiarían sustancialmente los efectos de la cuota sobre el recurso.

Se recomendó que se llevara adelante las recomendaciones propuestas en el panel de junio de 1970 sobre los efectos económicos de las medidas regulatorias en la pesquería de la anchoveta.

Panel de Julio de 1972

Esta fue la tercera reunión del panel de expertos en dinámica de la población de la anchoveta peruana; el autor participó como delegado del Ministerio de Pesquería.

A inicios del año 1972, comenzó a sentirse los efectos de una falla inesperada en el reclutamiento, el que se había encontrado estar a niveles sumamente bajos. Además, una introducción de aguas tropicales provenientes del norte a lo largo del litoral peruano ("El Niño") ocurrió en 1972.

Dentro de las recomendaciones dadas por el panel, se contemplaron varias alternativas: (a) Si se encontraba que la abundancia de peces había sido subestimada, una pesca limitada podría comenzar a fines de 1972; (b) Si las investigaciones indicaran que el reclutamiento, a comienzos de 1973, fuera bueno, podría pescarse limitadamente esta clase anual a partir de marzo de 1973; (c) Si se confirmaban las actuales estimaciones sobre la biomasa

Cuadro 3. Captura mensual promedio, producción de harina, rendimiento y número de plantas 1971.

Meses	Pesca mensual (T.M.)	N° de días de pesca	Pesca promedio por día (T.M.)	Producción harina (T.M.)	Rendimiento	N° de plantas
Enero	131,852	17	7,756	23,464	5,6	5
Febrero	150,917	20	7,546	28,820	5,2	5
Marzo	2'578,086	20	128,904	456,278	5,7	109
Abril	1'573,131	13	121,010	286,962	5,5	113
Mayo	689,991	10	68,999	129,413	5,3	113
Junio	97,493	6	16,249	18,536	5,3	29
Julio	(*)	(*)	(*)	2,208	–	–
Agosto	(*)	(*)	(*)	2,317	–	–
Setiembre	1'205,203	12	100,434	225,680	5,3	105
Octubre	1 357,809	11	123,437	265,471	5,1	107
Noviembre	1'155,206	7	165,029	229,167	5,0	109
Diciembre	1 342,096	10	134,210	266,285	5,0	110
Totales	10'281,784	126	119,295	1'934,601	5,3	116

de la anchoveta y el reclutamiento del año 1973 sería pobre también, no era recomendable empezar la pesca antes de setiembre de 1973; (d) Debe mantenerse la veda en todo caso de enero y febrero de 1973; (e) Se volvía a reafirmar la conveniencia de reducir el tamaño de la flota y la capacidad de las plantas industriales de acuerdo a la disponibilidad del recurso.

El panel manifestó no conocer bien la causa del bajo reclutamiento en la clase anual de 1971, el que podía ser debido al cambio de las condiciones ambientales que aunque no percibido por el hombre, es sin embargo apreciado por las especies billógicas, las que reaccionan de acuerdo a esos estímulos. Otra de las razones del bajo reclutamiento puede ser el menor desove en 1971 y la alta concentración del recurso, el que se apreció al estudiar las estadísticas de captura.

Regulaciónes Pesqueras (Vedas)

Conforme se iba desarrollando la industria pesquera y aumentando excesivamente la capacidad del esfuerzo pesquero de la flota anchovetera, se vió la necesidad de establecer controles con el objeto de proteger el recurso, ya a la propia industria. Por este motivo, ya desde el año 1965 el Estado ha ido dictando diversas disposiciones y normas de control, tratando de armonizar los diversos aspectos principales biológicos, industriales y socioeconómicos que intervienen en el problema.

Es a partir del año 1965 cuando el Ministerio de Agricultura, a través de la Dirección de Pesquería y Caza, que era la encargada del Sector Pesquero, decide establecer regulaciones en la captura de la anchoveta. Las principales regulaciones se indican a continuación.

Año 1965

El 17 de febrero se declara una veda de pesca de anchoveta en aguas jurisdiccionales peruanas, durante todo el mes de agosto.

Año 1966

Se dictaron varios decretos estableciéndose una veda durante los meses de julio, agosto y setiembre.

Año 1967

El 10 de febrero se dispuso que la temporada se clausurara al 31 de agosto de 1967, estableciéndose un período de veda del 15 de febrero al 14 de marzo; si prohibió también la captura de anchoveta durante los días sábado y domingo. En este año, se exoneró al Puerto de Ilo, dada su especial situación geográfica y las características del recurso en la zona sur del litoral, de las disposiciones para el resto de la República. Se estableció que la temporada 1967–68 se iniciara en dicho puerto el 1 de agosto de 1967. En el mismo período y para el resto del litoral se estableció que la temporada de pesca se iniciara el 1 de setiembre y terminara el 31 de agosto de 1968.

Año 1968

Se establece una época de veda de anchoveta del 17 de febrero al 17 de marzo de 1968 en todo el litoral con excepción del Puerto de Ilo. El 19 de abril se fijó una cuota máxima de captura durante el período del 1 de setiembre de 1967 al 31 de mayo de 1968, de 9,5 millones de toneladas, estableciéndose por tanto una veda durante los meses de junio, julio y agosto y fijando que la próxima temporada 1968–69 se iniciara el 2 de setiembre de 1968, subsistiendo la prohibición de pesca para los días sábado y domingo.

Año 1969

El 7 de enero se estableció una veda del 1 de febrero al 2 de marzo de 1969, con excepción del Puerto de Ilo. Se fija provisionalmente una captura máxima de 8,2 millones de toneladas.

El 15 de abril se establece una cuota máxima de anchoveta que las fábricas pueden recibir para su transformación.

El 13 de mayo se establece que la temporada de pesca finalizará el 31 de mayo de 1969. El 6 de junio se determina que las fábricas que empleen exceso de anchoveta a las cuotas fijadas serán multadas de inmediato.

El 29 de agosto se determina que la temporada 1969–70 se inicie el 1 de setiembre de 1969 y finalice cuando se capture el volumen autorizado.

El 25 de noviembre se suspende la prohibición de pescar la anchoveta los días sábado y domingo durante la temporada 1969–70.

Año 1970

Se establece una veda del 16 de febrero al 15 de marzo, exceptuando el Puerto de Ilo. El 5 de mayo se establece que se cerrarán los puertos pesqueros cuando el 30% o más de la captura desembarcada esté compuesta de ejemplares menores de 12 cm de longitud.

Se suspenden las actividades de pesca del 11 de julio al 31 de agosto para realizar un programa de embarcación de anchoveta.

Año 1971

El 14 de diciembre se establece un período de veda entre el 31 de diciembre de 1970 y el 28 de febrero de 1971, exceptuando Mollendo e Ilo.

El 18 de marzo se establece que los barcos solamente podrán capturar un 70% de su capacidad de bodega.

El 7 de mayo se establece una cuota máxima de captura de 9,8 millones de toneladas, y se suspende el 11 del mismo mes las actividades pesqueras en todo el litoral.

El 4 de junio se declara clausurada la primera parte de la temporada de pesca del año 1971 el 9 de dicho mes. En la segunda parte de este año, se empieza a establecer cuotas mensuales de captura paralizando las actividades pesqueras una vez alcanzada dicha cuota. Se fijaron como cuotas mensuales 1,2 millones de toneladas; asimismo, se prohibió la pesca los días viernes, sábado y domingo.

También se estableció regulaciones para las embarcaciones: las de 150 toneladas métricas o más pescarían los días lunes, martes y miércoles y las de menos de 150 toneladas métricas, los días lunes, martes, miércoles y jueves.

El 28 de agosto se establece que no debe de capturarse más de 10 millones de toneladas y que la segunda parte de la temporada de 1971 se debe de iniciar el 1 de setiembre y finalizará cuando se complete el máximo de captura autorizado que es de 4,8 millones de toneladas. Se prohibe la pesca en los días viernes, sábado y se fija en 1,2 millones de toneladas la captura autorizada durante el mes de setiembre.

Año 1972

El 24 de febrero se resuelve iniciar la temporada de pesca el 1 de marzo, prohibiéndose las actividades en los días sábado, domingo y lunes; se establece una captura de 1,8 millones de toneladas para este mes y un igual volumen para las actividades de pesca durante el mes de abril.

El 24 de mayo se autoriza trabajar a la flota de lunes a sábado, quedando por establecer el tonelaje de captura. Posteriormente, el 8 de junio se reduce la semana de trabajo a sólo cinco días, de lunes a viernes.

El 30 de junio se resuelve suspender la captura de anchoveta a partir del 3 de julio. La captura durante la primera parte del año 1972 llegó a 4,2 millones de toneladas de anchoveta.

Debido posiblemente a las condiciones ambientales producidas por un calentamiento de las aguas por la aparición del fenómeno "El Niño," que ha elevado la temperatura hasta 5° sobre el promedio, la fecha de iniciación de la segunda parte de la temporada del año 1972 no se ha determinado aún esperando el resultado final de los estudios que se están llevando a cabo a fin de determinar el estado actual del recurso y el nivel de explotación aconsejable.

Analisis

Como resultado de la sobrecapacidad y, por consecuencia de las regulaciones que se han indicado, dictadas con el objeto de proteger el recurso anchoveta teniendo en cuenta los otros factores del problema, la actividad pesquera peruana para consumo humano indirecto ha sufrido paralizaciones que afectan el desarrollo de sus operaciones y tienen impacto en las actividades económicas, tecnológicas y en el campo socioeconómico.

El presente estudio ha tratado de obtener diversas opiniones de los sectores interesados: el laboral, el empresarial, el científico y el periférico. Se ha conversado con personas que intervienen en la pesquería provenientes de las zonas norte (Chimbote, Huarmey y Supe), centro (Callao, Pucusana y Chancay) y sur (Tambo de Mora, Pisco, Mollendo e Ilo). En el sector laboral se consultó con patrones motoristas, pescadores y dirigentes sindicales; en el sector empresarial con administradores de fábricas y personal profesional; en el sector periférico con los dueños de diversos servicios como talleres de mecánica y otros. En el sector científico se ha tomado muy en cuenta las diversas publicaciones y comunicaciones del Instituto del Mar del Perú y los archivos de la Dirección General de Investigación Científica y Tecnológica del Ministerio de Pesquería.

Sector Laboral

El pescador tiene actualmente el concepto que las vedas se establecen para proteger el recurso, pero estando en un contacto permanente con el enorme recurso anchovetero que extrae del mar peruano, se le hace difícil comprender que éste puede agotarse y por lo tanto estima que las vedas son muy largas en tiempo y las cuotas de captura autorizadas muy bajas. Esta forma de pensar naturalmente está muy ligada al aspecto económico de este sector que probablemente es el más sensible al impacto de las regulaciones pesqueras.

El pescador no percibe un salario básico y dado que su remuneración depende de la captura que efectúa la embarcación, no tiene ingresos en las épocas en que la pesca está paralizada. Usualmente, el pescador no es natural del puerto donde tiene su base la embarcación, por lo que necesita hacer gastos de transporte y alojamiento. Durante las paralizaciones mensuales producidas al capturarse la cuota permitida para ese mes, que pueden variar entre 18 y 14 días sin trabajo, el pescador no tiene la oportunidad de obtener otra ocupación provisional, pero sí tiene que atender a sus gastos sin obtener ingresos. En la zona sur, o sea los puertos de Atico, Ilo y Mollendo, el pescador es más estable y tiene mayor conciencia social.

Ciertos dirigentes sindicales expusieron algunas soluciones. Entre ellas estaba la posible utilización de lanchas anchoveteras pequeñas que pudieran ser dadas de baja, para la pesca de consumo humano directo a través de la formación de cooperativas. También se habló sobre la necesidad de difundir los conocimientos básicos de los problemas importantes que afectan al sector pesquero, para una mayor comprensión dentro del elemento laboral.

Dentro de las opiniones sobre las medidas regulatorias, muchos pescadores coincidieron que para ellos era más conveniente el establecer una temporada ininterrumpida de pesca con una cuota de captura fija, lo cual podría ser alcanzada en cualquier número de días. Esto les permitiría trabajar en forma continua en las actividades pesqueras y desplazarse a sus lugares de origen, o buscar otras ocupaciones una vez alcanzada la cuota y finalizada la temporada. Hicieron fuerte hincapié sobre los inconvenientes de pasar muchos días del mes sin poder salir a pescar durante la temporada de pesca. La Federación de Pescadores del Perú ha hecho un estudio sobre su punto de vista de cómo solucionar el problema económico que las vedas presentan al pescador. Al comienzo el pescador acudía a la "Caja de Beneficios Sociales del Pescador" donde obtenía un préstamo a cuenta de vacaciones todavía no trabajadas, pagando intereses y gastos de administración; sin embargo, este sistema no le significa mayores ventajas. La Federación de Pescadores del Perú ha solicitado la creación de un Fondo Pro-Veda que alcanzaría a la fuerte suma de S/. 321'227,380 (Soles) US $4'600,000 con el cual dicen se solucionaría el problema de la veda en el 99,69% de pescadores inscritos en la Caja de Beneficios Sociales del Pescador, cuyo número total de miembros es de 24,007. La cifra indicada significaría el poder pagar aproximadamente S/. 4,200 (US $85) a cada pescador durante los tres meses de veda anual, ya que en el cuarto mes reciben un haber correspondiente a vacaciones anuales.

Los pescadores solicitan que la suma de S/. 231'227,380 (US $4'600,000) sea pagada por los armadores. Tomando como índice la capacidad de bodega de la flota, ésto representa un costo anual de S/. 897 (US $18) por tonelada de capacidad de bodega, lo que significaría para una lancha de 350 toneladas métricas un mayor gasto de aproximadamente S/. 313,000 (US $6300). En caso se tomara como índice una captura promedio anual de 10 millones de toneladas, el mayor costo por tonelada de anchoveta sería de S/. 23 (US $0.50). Actualmente el armador recibe por tonelada de anchoveta S/. 550 (US $11.00) y paga a su tripulación S/. 151 (US $3.00) por tonelada, corriendo de su cuenta el pago del sueldo del motorista.

El sector laboral en el año 1971 recibió una participación en la actividad pesquera de S/. 1,490'000,000 (US $30'000,000), sin considerar gratificaciones ni beneficios sociales.

SECTOR EMPRESARIAL

Este sector en general acepta y comprende las regulaciones pesqueras que protegen al recurso anchoveta. Aprecia la fuerte incidencia ecónomica en las empresas ya que durante las épocas de veda los gastos fijos continúan corriendo sin tener ingresos por producción. El sector empresarial de los puertos de Mollendo e Ilo considera que su zona debería de estar marginada de las regulaciones pesqueras ya que la mayor parte de las veces siempre encuentran pescado y temen que si el recurso no es aprovechado por ellos en la zona sur, éste puede ser explotado por embarcaciones provenientes de la zona pesquera del norte de Chile que explota la misma subpoblación.

La gran preocupación en este sector es la más eficiente explotación del recurso. En este sentido opina que cuando aparecen grandes cardúmenes de anchoveta, no es conveniente una paralización al alcanzar la cuota mensual fijada, ya que éstos pueden alejarse o desaparecer de la zona no encontrándose así al reiniciar la pesca al mes subsiguiente. Algunos empresarios consideran que en caso de aparecer un abundante cardumen, se debe de pescar sin límite de cuota mensual y más bien sumar la cuota del mes en que apareció el recurso con las cuotas de los meses subsiguientes; de esta manera se aprovecharía el recurso y no se sobrepasaría de la cutoa total fijada para la temporada.

La industria plantea que el control de la cantidad de anchoveta que las fábricas pueden recibir conforme a su capacidad de reducción registrada, sea en términos semanales y no diarios, ya que a pesar que hay un 5% de tolerancia, ésto no evita que las fábricas sean sancionadas por recibir, sin proponérselo y sin poder evitarlo, mayores volúmenes de materia prima.

Durante el año 1970, según la Memoria de la Sociedad Nacional de Pesquería, solamente se produjeron 90 días autorizados para la pesca, debido a las paralizaciones por regulaciones pesqueras, lo cual ha incidido negativamente en la programación industrial de las empresas.

SECTOR CIENTIFICO

Dentro del aspecto biológico, las vedas son importantes para la protección de los desovantes y de la clase recluta, o sea en general de todo el recurso anchoveta. Naturalmente, siempre hay cierta discrepancia de opiniones entre los sectores industrial y laboral, y el científico, ya que éste último al recomendar medidas de protección va en cierta forma contra los intereses economicós de los otros sectores

Un factor importante que debe de considerarse es que el stock de la anchoveta no puede ser tratado como un stock de mercadería depositada en un almacén donde se puede establecer salidas diarias determinadas. El recurso anchoveta es una biomasa que se desplaza y cuyas actitudes son imposibles de determinar con exactitud, por lo que podría suceder que si no se pesca en forma eficiente con todo el esfuerzo pesquero tratando de alcanzar las cuotas recomendadas, en cualquier momento puede desaparecer el recurso con lo que se asumiría una gran responsabilidad al haber limitado la captura o tratado de repartirla en períodos interrumpidos.

Basado en los conocimientos actuales adquiridos con las investigaciones realizadas y siempre y cuando las condiciones ambientales sean normales, la regulaciones básicas de la pesquería podrían ser, en la opinión del autor: (a) Dos meses de veda en enero y febrero (veda de verano); (b) Establecimiento de una cuota de captura de aproximadamente 4,5 a 5 millones de toneladas para la primera parte de la temporada anual que no podría exceder del 30 de junio. Este total sería conveniente distribuirlo por meses, (c) Semanas de trabajo de 4 a 5 días; (d) Establecimiento de una veda durante los meses de julio y agosto (veda de invierno); (e) Reiniciar la temporada el 1 de setiembre hasta el 31 de diciembre, fijando una cuota de captura dependiendo del desarrollo de la pesquería y de las investigaciones durante la primera parte de la temporada.

Este sistema da protección a los peces jóvenes y evitaría el clausurar los puertos por la aparición de peladilla; asimismo, permitiría a la industria el poder planificar su desarrollo y por tanto hacerse más eficiente.

Dentro de los resultados apreciados al aplicar las regulaciones sobre todo en la época de verano (enero y febrero), se ha constatado, según las investigaciones realizadas, lo siguiente: (a) Se incrementa la captura por unidad de esfuerzo; (b) El peso promedio de los peces en la captura aumenta; esta condición permite obtener un mejor rendimiento en el proceso de reducción; (c) Se obtiene una reducción del esfuerzo de pesca.

SECTOR PERIFERICO

Siendo la actividad pesquera una de las más importantes del país que da trabajo a aproximadamente 24,007 pescadores y a 6000 a 7000 trabajadores de plantas sin contar el elemento profesional y directivo, las actividades que giran alrededor de esta industria dependen para la subsistencia, del desarrollo de ella. Como referencia podemos decir que la actividad pesquera en el año 1970 contribuyó a un ingreso de divisas para el país de 347 millones de dólares, la producción de harina y aceite de pescado aportó 316 millones de dólares, o sea el 35%.

En general, sobre todo en los puertos pesqueros tales como Chimbote, Tambo de Mora, Supe y otros donde la actividad pesquera representa un alto porcentaje del total de actividades, los negocios de alimentos, de artículos para el hogar y transporte, disminuyen en forma sensible, sobre todo en la época de las vedas bimensuales. Como compensación, los negocios de servicios, ferretería y repuestos para motores e implementos pesqueros aumentan dado que es generalmente la época de reparación más apropiada para las embarcaciones y redes.

Una de las actividades más afectadas por las regulaciones pesqueras es la de construcción de embarcaciones anchoveteras. Con fecha 6 de julio de 1971, siguiendo las recomendaciones para reducir el esfuerzo pesquero de la flota anchovetera y más bien dirigir la actividad de construcción naval a la pesca de consumo humano directo, se dictaron las siguientes regulaciones: (a) Se declaraba la caducidad de las matrículas de los barcos anchoveteros que no habían pescado del 1 de setiembre de 1969 al 1 de setiembre de 1970; (b) Los propietarios que desearan construir nuevas embarcaciones anchoveteras deben retirar para cada tonelada de capacidad de bodega que ingresa, una tonelada y media de capacidad, como mínimo, de su flota; (c) Esta disposición se mantendrá hasta ver alcanzado el tonelaje de capacidad de bodega permisible, teniendo en cuento el equilibrio que debe de existir entre las fases de extracción y transformación por empresa.

En consecuencia estas medidas han hecho disminuir la construcción de embarcaciones anchoveteras que era el rubro de mayor actividad de los astilleros nacionales.

CUADRO 4. Producción peruana de harina y aceite de pescado (T.M.) 1960–71.

Años	Harina	Aceite
1960	529,971	48,211
1961	863,766	118,886
1962	1'120,796	150,784
1963	1'159,233	154,871
1964	1'552,214	165,026
1965	1'282,011	124,880
1966	1'470,478	146,708
1967	1'815,983	291,819
1968	1'922,020	292,250
1969	1'610,778	148,839
1970	2'253,439	310,765
1971	1'934,601	409,137

NUEVA SITUACIÓN

Con fecha 7 de mayo de 1973, el Gobierno Peruano promulgó el Decreto Ley Nº 19999 creando la Empresa Pública de Producción de Harina y Aceite de Pescado "PESCAPERU" para que lleve a cabo, directamente y en forma exclusiva, las operaciones destinadas a la extracción y transformación de la anchoveta para harina y aceite.

Por Decreto Ley Nº 20000, de la misma fecha, el Gobierno Peruano, considerando, que la anchoveta es un recurso natural y aleatorio que pertenece a todo el pueblo peruano; que la estructura de la industria era deficiente y estaba desequilibrada; y que era necesaria la racionalización de ella, para superar la situación, bajo el control y administración del Estado, decretó:

> "Declarar de interés social y necesidad pública la extracción y transformación de la anchoveta para harina y aceite, expropiando a favor del Estado las acciones de las empresas particulares".

Las anteriores medidas han cambiado sustancialmente las situaciones que se describen y analizan en este documento.

Industrial Fisheries and Their Influence on Catches for Human Consumption[1]

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Popiel, J., and J. Sosinski. 1973. Industrial fisheries and their influence on catches for human consumption. J. Fish. Res. Board Can. 30: 2254–2259.

Fish meal production may be based on a variety of raw materials such as: fish offal obtained during the processing of fish for human consumption; by-catches obtained from catches for human consumption; fish and other marine organisms not used for human consumption, but landed especially for industrial purposes, such as sand eels, Norway pout, etc.; surplus of fish caught for human consumption when abundance permits increased catches.

Objections are raised against industrial catches when they are in competition with catches for human consumption. In such cases considerable losses of nutrients may occur because only a portion of the protein and fat contained in fish meal is assimilated by animals to which it is fed. Simultaneously the expansion of industrial catches of fish suitable for human consumption reduces the supply of fish products.

Uncontrolled expansion of industrial catches will drive fleets which catch fish for human consumption off their usual grounds. Herring fishing in the northeast Atlantic is an example of one forced out by industrial catches. Recently mackerel catches in the North Sea have shown the same trends.

In future, more fish stocks may suffer from overexploitation caused by competition between food fisheries and industrial fisheries. Whenever fish resources are simultaneously exploited for these two purposes, and regulation is necessary, management should first aim at satisfying the demand for fish for human consumption. This is to some extent the case with minimum size limits, but not with quotas. In assigning quotas, consideration should be given both to sizes of fish caught and to intended use of the fish.

On peut utiliser une grande variété d'organismes marins pour fabriquer de la farine de poisson. L'emploi d'un certain nombre d'entre eux se justifie pour les raisons suivantes: déchets de poisson provenant de la transformation du poisson destiné à la consommation humaine; prises accessoires accompagnant les poissons capturés pour la consommation humaine; poissons et autres organismes marins non utilisés pour la consommation humaine mais capturés spécialement à des fins industrielles, par exemple, lancons, tacauds norvégiens, etc; excédents de poissons capturés pour la consommation humaine, lorsque l'abondance des stocks permet un accroissement des prises.

Des objections sont formulées à l'encontre des captures industrielles quand elles concurrencent les captures destinées à la consommation humaine. Dans de tels cas, des pertes considérables de substances nutritives peuvent survenir, car seule une partie des protéines et des lipides que renferme la farine de poisson est assimilée par les animaux auxquels elle est donnée comme nourriture. Parallèlement, l'expansion des captures industrielles de poissons comestibles humaine réduit les disponibilités de produits de la pêche.

L'expansion démesurée des captures industrielles obligera les flottilles qui capturent des poissons pour l'alimentation humaine à abandonner leurs zones de pêche habituelles. La pêcherie de hareng dans l'Atlantique Nord-Est est un exemple de pêcherie éliminée par les flottilles industrielles. Des tendances analogues sont observées depuis peu dans la pêche au maquereau en mer du Nord.

Il se peut qu'un plus grand nombre de stocks souffriront à l'avenir de la surexploitation provoquée par la concurrence entre la pêche alimentarie et la pêche industrielle. Chaque fois que des ressources ichtyologiques sont exploitées simultanément à ces deux fins et qu'une réglementation est nécessaire, les activités d'aménagement devraient viser avant tout à satisfaire la demande de poisson comestible. C'est ce à quoi tend dans une certaine mesure la fixation de limites minimales de taille, mais non le contingentement. Lors de l'affectation des contingents, il faudrait prendre en considération à la fois la dimension des poissons capturés et l'usage auquel le poisson est destiné.

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

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Para la producción de harina de pescado está justificado emplear diversos organismos marinos: los desechos obtenidos durante la elaboración del pescado destinados al consumo humano; los animales marinos capturados accidentalmente, con los peces destinados al consumo humano; el pescado y otros organismos marinos no destinados al consumo humano, descargados especialmente con fines industriales, como lanzones, faneca de Noruega, etc; los sobrantes de lo pescado para el consumo humano, cuando la abundancia de peces permite aumentar las capturas.

Se hacen a veces objecciones a las capturas para fines industriales, cuando entran en comptencia con las destinadas al consumo humano. En estos casos pueden producirse pérdidas considerables de sustancias nutritivas, ya que solo parte de las proteínas y las grasas contenidas en la harina de pescado non asimiladas por los animales a quienes se alimenta con ella. Al mismo tiempo, la expansión de las capturas, con fines de reducción, de peces adecuados para el consumo humano, reduce el abastecimiento de productos pesqueros.

Una expansión incontrolada de las capturas destinadas a fines industriales obligaría a diversas flotas dedicadas a la pesca para el consumo a abandonar sus caladeros habituales. Un ejemplo de esto es la pesquería de arenque del Nordeste del Atlántico. Recientemente, también con las capturas de caballa del Mar del Norte ha sucedido lo mismo.

Es posible que en el futuro aumente el numero de poblaciones de peces excesivamente explotadas a causa de la competencia entre las pesquerías para el consumo y para usos industriales. Cuando los recursos pesqueros se explotan simultáneamente para estos dos fines y es necesaria una regulación, es preciso tender ante todo a satisfacer la demanda de pescado para consumo humano. Esto es lo que se logra, en cierta forma, al fijar límites mínimos de talla, pero no al determinar cupos. Al asignar cupos, es preciso tener en cuenta tanto la talla de los peces capturados como el uso a que se destinan.

World Production of Fish Meal

A steady rise in the world production of fish meal[2] has been noted in recent years. This trend was interrupted in the years 1965 and 1969, when production decreased below the figures of previous years; this was influenced by a drop in production in Peru, which is the biggest producer of fish meal. The production of fish meal in-

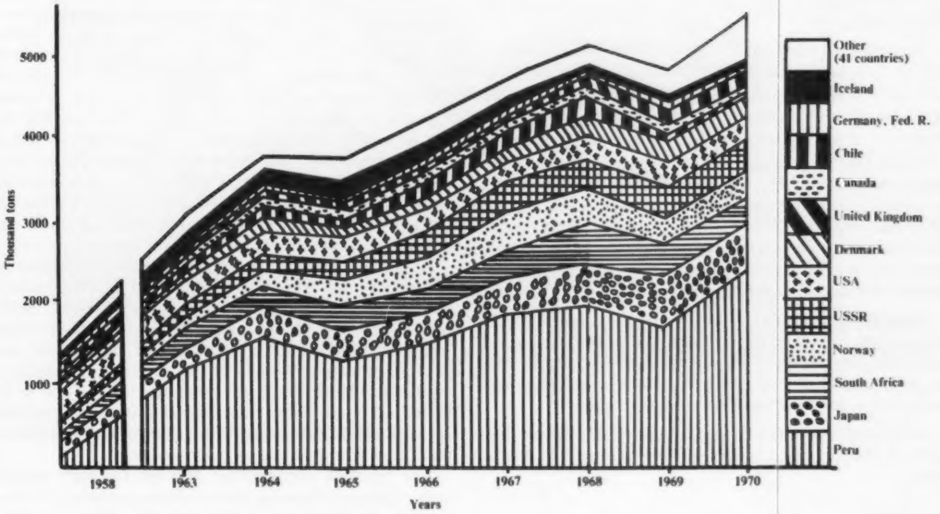

FIG. 1. World fish meal production from 1958 to 1970.

creased from 1,525,000 metric tons in 1958 to 5,440,000 metric tons in 1970 (Fig. 1).

Rapidly expanding industrial catches along with steadily increasing fish meal production in the last decade have been watched with anxiety by countries whose fishing fleets operate mainly for fish for human consumption. No high-quality requirements are necessary for fish for industrial purposes; both fish of small size and those not necessarily fresh are utilized. Accordingly it is relatively easy to organize fisheries for fish meal on a large scale, and these may become more dangerous to fish resources than traditional catches of fish for human consumption.

Raw Materials Used for Fish Meal Production

Meal can be produced from various kinds of marine organisms, which can be divided into the following groups: marine mammals (whales); invertebrates; and fishes.

The production of meal from whales in 1958 amounted to 93,000 metric tons which was 6.1% of the total fish meal production. In the following years this figure decreased in both absolute amounts and in percentage terms; in 1970 only 54,000 metric tons of meal were produced from whales, this being only 1.0% of the world production.

The quantity obtained from crustaceans and molluscs was also insignificant, amounting to 15,000 metric tons, which comprised only 0.3% of the total meal production in 1970. Meal from such species was produced mainly by the United States.

The rest of the fish meal, over 90%, was produced from fish as follows: offal obtained during the processing of fish for human consumption; poor quality fish and the so-called by-catch[3]; fish not usually eaten; fish usually eaten.

These raw materials can be obtained either as by-products from fishing for food fish or during special so-called industrial catches. Most of today's fish meal is obtained from the latter. Statistics specifying the type of fish utilized in the production of meal are differentiated into bottom species (which are mainly lean) and pelagic species (which are relatively fat).

Most fish processed into meal are pelagic species. The proportion of meal produced from these has increased in recent years: in 1958 it amounted to 80%, and in 1968 it comprised 91.6% of all the meal produced. The main sources are anchovies and herring-like fishes.

Estimated amounts of some species of fish for production of meal in 1970 is shown, in thousands of metric tons:

Anchovies	13,800
Sardines	1,100
Herring	600
Menhaden	850
Mackerel	300
Capelin	1,500
Sand-eel	400
Horsemackerel	100
Norway pout	300
Rockfishes	100
Alaska pollock	1,000
Total	20,050

About 20 million metric tons of these fishes were processed, which corresponds to approximately 4 million metric tons of meal. The remaining meal produced, which amounted to 1,440,000 metric tons (Fig. 1), was from fish offal, whales, invertebrates, and other species of fishes not included in the table.

Edible and Inedible Species

Fish meal is produced from various raw materials as discussed above. Reservations about the wisdom of such production does not arise from use of by-products of fishing for food fish.

Special industrial catches utilize fish generally inedible, such as sand-eels, Norway pout, capelin, menhaden, etc., and fish generally edible, such as herring, mackerel, sprats, sardines, and anchovies. The catching of young edible fish for meal is a special case.

It is sometime difficult to distinguish between edible and inedible fish. Those which are considered edible in some countries are not eaten in others; at some periods the biological state of fish classifies them as suitable for human consumption, while at other times, for instance after spawning, only as raw material for meal. A typical example of this is sprat; in the Baltic, for instance, they are unsuitable for consumption during the summer season.

Production of meal from fish not usually edible is rational, since the protein is utilized for producing meat which is more attractive for human consumption than the original form. However, during the exploitation of such a fish stock, care should be taken not to overfish them.

Industrial catches of fish generally edible can give rise to reservations; nevertheless, an important differentiation should be introduced. There are many species of edible fish which occur in huge amounts and yet, due to their small size and quick deterioration, cannot be used for consumption profitably by existing technological methods. The demand for these species as food is frequently limited, being less than the amounts available. In such cases catching and processing these species into meal does not give rise to reservations.

The problem is altogether different for such valuable edible species as herring and mackerel, especially in those regions where overexploitation has reduced the stocks to such an extent that regulation of the fishery is necessary.

Review of Some Industrial Fisheries

The largest amount of meal is produced from anchovy. This is basically an edible species, but at the

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[2] In this paper fish meal is used to designate all meal for animal feeding produced from marine fauna.

[3] The term by-catch is used here for all types of fish which, for various reasons, are not or cannot be preserved for direct consumption. This comprises fish which are small or inedible, or which, although edible, cannot be processed on board.

present level of technology it does not seem possible to utilize very large available quantities of this fish for human consumption, and consumer demand is limited. Thus, at present, the processing of anchovy into meal appears to be the only means of making full use of such large stocks. The situation is somewhat similar for sardines, which are bigger than anchovies, however, and stocks are smaller. Already a considerable part of sardine catches is sold for human consumption. Even so, during the next few years it does not seem possible to use all, or even most, of the possible sardine catches for human food. Meal production from sardines is concentrated along the coast of West Africa, where stocks are fished intensively and reserves are not extensive. Sardine fishing for human consumption is expanding in these waters, and competition is expected between this fishing and that for the production of meal. From the point of view of rational utilization of stocks, the industrial sardine fishery should be restricted and the interested fleets directed to the exploiting of other, less valuable stocks.

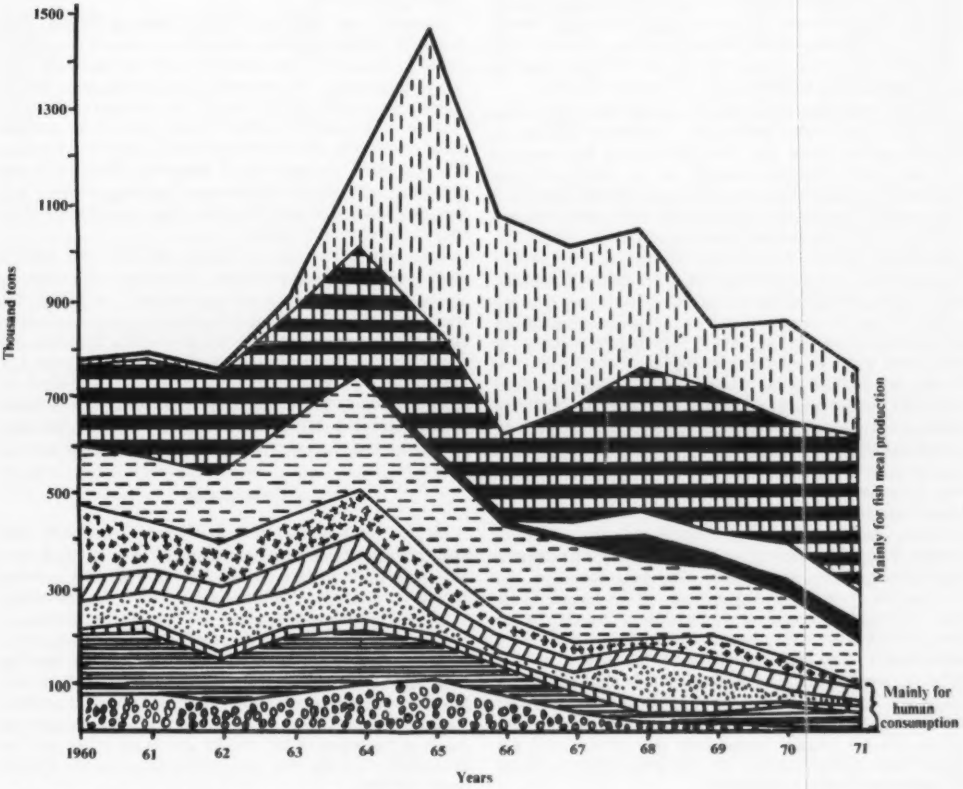

FIG. 2. Herring catches in the North Sea, 1960–71.

For Alaska pollock, the 1 million metric tons shown as being destined for the production of meal is based on uncertain estimates. In some countries Alaska pollock is treated as an edible fish, whereas in others — in view of the poor quality meat and high degree of parasitic infection — it is processed into meal. Fish sausage is made from this species in Japan. It is difficult to state whether competition exists between fishing pollock for purposes of human consumption and that for meal production.

The use of herring and mackerel for production of meal and oil gives rise to the greatest reservations. The North Atlantic stocks of these fish are being utilized very intensively, as the result of which they have been considerably reduced. The problem of competition between industrial and food fisheries is especially difficult in the North Sea. In the Norwegien Sea intensive fishing, together with unfavorable natural conditions for recruitment, has led to disappearance of both kinds of herring fisheries.

In the North Sea and adjacent waters there have been distinctly unfavorable influences of industrial catches on herring stocks. Since the 1950s fishing has been carried out for young herrings, mainly on the Bløden fishing grounds in the southeast part of the North Sea are a nursery for herring, and because of their small size the number of fish in the catch is large. Similar fishing for young herring takes place in the Skagerrak. Fishing for young herring has an unfavorable influence on catches of adults, since it takes the young fish before they are big enough to be of value for direct consumption. In addition to the fishing for young herrings, industrial fishing for adult fish became intensive during the 1960s.

Herring catches in the North Sea amounted to about 900,000 metric tons annually in the years 1950–63. In 1964 they rose to 1,319,000 metric tons, and in 1965 to 1,565,000 metric tons. During the following 3 years they stayed around 1 million metric tons, while in 1969 there was a sudden drop. The large catches in 1964 and 1965 were made by a large seiner fleet which had formerly been working the Norwegian Sea. Catches rose from 3,200 in 1963 to 595,400 metric tons in 1965, mostly in the northern part of the North Sea. These were large herrings, the average length in 1965 ranging from 26 to 30 cm. Most were 3–5 years of age. Over the next few years, due to the lack of older herrings, younger, immature herrings were also caught. The high catches were the reason for the drop in later years. The mortality rate increased considerably, and diminishing herring stocks reduced the catch rates, especially of boats using bottom trawls. Older fish are usually found near the bottom and are fished with bottom trawls for the food market; these disappeared almost completely.

Figure 2 illustrates the influence of industrial catches on fishery for human consumption in the North Sea. The amounts of fish caught by the various countries in 1960–69 are given in the form of strips. The order in which the catches of countries are shown is the percentage of herring caught which was processed into fish meal. Thus, the upper part of the figure gives the catches of the countries fishing mainly for fish meal and the lower part those fishing mainly for human consumption.

As can be seen, there was an increase (or a stabilization on a relatively high level) of catches by countries with industrial fisheries. Figure 2 also illustrates quite clearly the declining tendency of catches by the countries utilizing herring for direct consumption in the last few years. Intensive catches for meal influenced the drop in catches for food; this drop was about 200,000 metric tons annually.

In this the Polish fisheries were especially hard hit. They fish for adult herring for human consumption, using mainly bottom trawls. Lack of large herrings and diminished output from bottom catches forced some vessels to look for more favorable conditions in other regions. Polish herring catches from the North Sea dropped rapidly from 109,000 metric tons in 1965 to 2,500 metric tons in 1971.

Summing up, catches of young herring for fish meal from the Bløden grounds, and in recent years the intensive fishing for adults in the northern part of the North Sea, has resulted in a serious depletion of adult herring, and has considerably reduced the stocks. As a result, fishing for human consumption suffered particularly, as suitable stocks were lost. It was impossible for these fleets to face the economic competition of industrial fisheries. Apart from this, excessive exploitation of herring stocks led to overfishing, and if the situation does not change there will be further regression.

Industrial fishing in the North Sea has also had an unfavorable influence on fishing for mackerel for human consumption. There was a rapid increase in North Sea mackerel catches in 1964–67 (Table 1), but a gradual drop took place over the following 2 years. The increase was primarily due to an expansion of industrial fishing. The result was similar to that for herrings, and landings of mackerel for direct consumption decreased. As a result of this situation, large amounts of protein and fat were lost or degraded, a serious problem in a time of protein deficiency.

Conclusion

1) Industrial catches may be based on juvenile fish, and intensive exploitation of these leads to a catch of a major part of the stock before fish reach the size suitable for consumption, and before they are ready for spawning.

2) The handling of catches for fish meal is comparatively simple and does not involve high labor expenditure. Thus it is possible to use an efficient kind of gear, landing large quantities of fish within a short time. This is why purse seines have been so widely used in industrial catches. The use of such highly efficient gear on a large scale can result in depletion of fish stocks and bring to an end the profitability of the less productive fisheries for human consumption.

3) Fisheries for industrial purposes do not show as much concern for maintaining stocks of fish as fisheries for food. This comes from a greater flexibility of the former, which having overfished one species can easily shift to another, since the kind of fish exploited is of little importance. By contrast, food fisheries must satisfy a demand for some particular species, this demand arising from habits and preferences of consumers established over many centuries of tradition.

Industrial catches compete with fisheries for human consumption in only a few fish stocks, but in future more

Table 1. Mackerel catches in the North Sea and the Skagerrak in 1963—1971 (in metric tons).

Country	Years								
	1963	1964	1965	1966	1967	1968	1969	1970	1971
Norway	23,350	51,383	156,604	484,428	866,548	779,084	683,045	278,631	200,635
Sweden	21,397	15,006	13,364	13,754	15,246	11,783	10,820	4,407	3,163
Denmark	6,878	6,311	6,509	7,552	20,282	9,887	10,851	26,753	17,590
Germany (F.R.)	1,769	3,495	2,221	1,501	2,132	1,353	1,161	225	407
United Kingdom	1,974	921	–	–	788	583	–	183	639
France	967	9,901	7,535	5,390	7,400	4,684	11,353	4,677	8,953
Belgium	118	125	138	67	201	77	139	19	85
Netherlands	11,846	17,085	16,977	12,247	10,801	5,864	4,928	2,956	4,945
USSR	1,690	3,153	227	1,778	4,098	6,094	12,516	718	2,600
Poland	3,110	7,617	3,700	2,290	2,261	1,629	12	205	130
Others	–	–	1,191	7,721	191	407	3,958	3,626	4,252
Total	73,099	114,997	208,466	529,728	929,948	821,445	738,783	322,400	243,399

may suffer from such competition. Therefore our opinion is that whenever fish resources simultaneously exploited for fish meal and for human consumption decrease from overfishing, fishery regulations should at first aim at satisfying the demand for fish for human consumption.

Regulations establishing either minimum mesh size or minimum fish length act somewhat in favor of fisheries for human consumption, since they lead to landings of higher quality fish, and this prompts the fishermen to take better care of the catch to protect it against spoilage. It is quite another matter with a catch quote regulation. A quota is defined in weight units and may consist of a great number of juvenile individuals caught before their first spawning, or of a smaller number of adult fish.

Where competition between industrial catches and catches for human consumption is intense enough to call for regulatory measures, such measures should tend to reduce to a minimum possible loss of nutritious substances. Particularly when need arises for catch quotas, i.e. as soon as the management of the resources is started on an international scale, the demand for fish for direct human consumption should be given priority over industrial catches. When distributing quotas for a given fish stock, consideration should be taken both of the size of the fish and of the intended use of the catch. Measures should be taken which would prevent industrial industries forcing from the fishing grounds fleets operating for human consumption.

Report on Technical Session IV—Section 1

Peru

1. Much of the discussion centered on Peru, where the principal fishery is for the small, short-lived anchoveta. This fishery grew rapidly. This development occurred because of the two key factors — a large resource and a big market for fish meal. Data available indicated that the limit of the sustainable yield from the resource was 10–12 million tons, and this limit was reached by 1967. For the last 5 years, therefore, Peru has been faced with management problems. Although there are still doubts as to whether increased fishing effort would mean a collapse of the stock, this possibility is very real. In any event, increased effort would result in little if any increase in landings. Also, a great amount of excess catching and processing capacity has built up.

2. A series of management measures has been introduced. A closed season on January–February has been set to protect the small fish, which are particularly abundant at this time of year. Another closed season in July–August is set to limit the total amount of fishing, which is also controlled by monthly or seasonal quotus, allowing fishing on certain days in the week only. Management policies have had to make allowance for the fact that the fishery employs 24,000 fishermen and 6000–7000 men in shore plants, and that it is the country's most important source of foreign currency.

3. Fishermen are paid only on the basis of their catch and have no earnings when they are not fishing. A fund has been requested to provide them with money during the closed season.

4. Peru has not been successful in avoiding serious overcapitalization of the fishery both in terms of vessels and of plants. Efforts are being made to transfer some of the excess vessels to fisheries taking fish for human consumption. However, conversion costs are high and owners want to divert only their less efficient vessels. Voluntary restrictions on vessels are not effective because the owners try to increase the size and numbers of their craft. Some of the plants are inefficient and waste raw material. The Government is taking steps to deal with this problem by creating a contingency fund to cover the debts of the plants going out of business.

5. Special problems have arisen because of the sharp decline in the fishery in 1972 due to the low abundance of fish recruited in the beginning of the year. Though the precise causes of the recruitment failure are not certain, they may be related to oceanographic phenomena. It is, however, clear that difficult decisions needed to be taken if the future of the fishery was to be answered. To avoid lasting damage to the stock, very severe restrictions were in fact introduced in the second half of 1972.

6. Fishing in 1973 will depend basically on the size of recruitment at the beginning of 1973. Preliminary events suggest that it will not be up to average.

7. The experience of management of the anchoveta fishing, and especially the events of 1972, show that certain scientific questions urgently need answering, these include: how large a quota should be established; how to adjust models and quota to fluctuations in the environment; how to obtain early measurement of the strength of recruitment for early adjustment of the quota; what is the effect of the fishery on annual recruitment; what are the ecological interactions of the anchoveta with other fish and with bird life.

8. The anchoveta fishery illustrates many things discussed at the Conference, e.g. the possibilities for rapid development; a quick rise to significant overcapacity in fishing and processing facilities; danger of collapse if fishing effort continues to increase; in discriminating a need for management based on research, and for action taken before data are complete, but with flexibility to meet changing conditions; need for a strong link between research and management; and the assistance that can be given by outside bodies like FAO.

Ecuador

9. The fishing industry of Ecuador is at an early stage, with an annual production of 100,000 tons. Management is based on the principle of self-help and individual responsibility. The aim of the 5-year plan is maximum utilization of the fish as food.

10. Tuna fishing is handled on the basis of private enterprise operating in coastal areas while the government operates the distant water fishery. The overall fishing operation is directed to human consumption and only the waste goes into meal. The Government buys fish from the artisanal fishery and sells to the retail merchants. The artisanal fishery is organized into co-ops.

Chile

11. The Government now operates the fisheries, including processing plants. As in Eucador, the industry is only at an early stage of development. Production rose from 110,000 tons in 1952 to 1.6 million in 1971, of which 1.3 million tons was anchoveta.

12. The Government is looking at alternative sources of fish and is building up shore and fleet facilities with foreign aid. The aim is to make the fishery the country's second largest producer of foreign exchange.

Common Features in the Three Countries

13. There is a need for government intervention, especially in the complex food fish industry; it is easier for the private sector to operate on fish meal. However, in Peru, Government and the private sector are working closely together.

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14. Certain fisheries, such as the fish meal and shrimp fisheries are very valuable as an earner of foreign exchange. These earnings should be used for the development of other sectors of the economy to encourage diversification. These export-orientated fisheries can also develop valuable managerial expertise, which can be usefully employed in developing their fishery.

15. Scientific work has been of great value in Peru, but more needs to be done, both there and in the neighboring countries. Very successful research services are now supported by FAO/UNDP following several years of cooperation with Peru, one result of which was the establishment of an excellent research agency.

16. Good communications exist in all three countries between scientists and decision makers. This works both ways: administrators are aware of the scientists' findings and scientists are aware of the most urgent research needs.

17. Credit is available for both the fishery and industrial development. National institutions and national fishing fleets built up with foreign assistance and improvement of local management services have enabled the countries to take full advantage of the contribution of foreign experts.

Fish Meal

18. Emphasis was placed on the importance of making fish meal from fish offal, fish taken incidentally to catches for human consumption, marine organisms not used for human consumption, and surpluses to food requirements. It would appear that due to the development of their sources of protein, future markets for meal are not likely to increase to nearly the same extent as those for food fish.

19. It was pointed out that the food fish industry is more "labour-intensive" than the meal industry and demands more careful handling of the product. In Peru, the creation of a State Food Fish Company operating in tandem with private industry, was a new concept. It appears to be working well. There are certain things which the state can do which are difficult for the private sector. In this case, the state is functioning as both a regulator and a shareholder.

20. In relation to the management of heavily fished stocks, and the possible imposition of regulations determining the use that should be made of the catches, it was pointed out that if quotas are imposed, the quota holders would use their allocations for direct food consumption or for meal according to their particular circumstances and what would provide the best returns.

Need for Oceanographic Research

21. A knowledge of, and the ability to predict oceanographic conditions can be very valuable for fisheries. There is a growing expectation that within the present century, long-term and medium-term prediction of oceanographic conditions will become possible. If these predictions are to be fully utilized by the fishery industries and administration, there must be a better understanding of the fish stocks, and the impact of environmental changes on them.

FAO Technical Conference on Fishery Management and Development

TECHNICAL SESSION IV — SECTION 2

Regional and Other Case Studies — Eastern Central Atlantic

CHAIRMAN: E. O. BAYAGBONA

Management and Development of Fisheries in the Eastern Central Atlantic[1]

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The resources of the eastern central Atlantic can be divided into two parts: the northern, temperate or subtropical zone in an area where cool upwelling water gives high production of pelagic species like the sardine, sardinella, mackerel, and horsemackerel, and of demersal species like the various sea breams, hake, and several species of cephalopods; the tropical zone, roughly from Cape Verde southward, is less rich although it contains a great variety of species.

Distribution of human population and of potential local markets is uneven, the greater part being in the tropical area. Except for the sardine and other fisheries of Morocco, the main locally based fisheries have been in this region. Until recently there have been mostly small inshore canoe fisheries, but the rich upwelling areas have been a strong attraction for fishermen from outside the region. These have included trawl fishermen from southern Europe, mainly interested in high-value species such as sea bream; Japanese fishermen interested in these same species and in squid, octopuses, and cuttlefish; fishermen from eastern Europe, using trawls (later purse seines) for pelagic species such as mackerel and horsemackerel; and fishermen from Scandinavia and South Africa, catching pelagic fishes, particularly sardinellas, for reduction to fish meal. Local countries have been developing their fleets; in the tropical area these include large long-range vessels for operating in the richer areas to the north and also to the south in the Benguela current.

Several stocks in the region have become or are becoming heavily exploited. Necessary management action includes collecting and analyzing the basic data to assess the stocks, limiting the total amount of fishing to the level appropriate to each stock, and assuring an increasing participation in the offshore fisheries by coastal African countries.

There is clearly a need for bilateral or multilateral arrangements between countries in the zone of high human population but low fish production and countries in the more productive but less populated zone. This would benefit both groups and stimulate intra-African trade and cooperation.

Du point de vue des ressources, on peut diviser l'Atlantique centre-est en deux parties: la zone nord, tempérée ou subtropicale, où des remontées d'eaux profondes assurent une production primaire élevée, tant d'espèces pélagiques comme la sardine, la sardinelle, le maquereau et le chinchard, que d'espèces démersales, telles que sparidés divers, merlus et plusieurs espèces de céphalopodes; la zone tropicale qui part à peu près du cap Vert et s'étend vers le sud, est moins riche, bien qu'elle soit peuplée d'une grande variété d'espèces.

Les populations humaines et les marchés locaux en puissance sont inégalement répartis et concentrés dans la zone tropicale. A l'exception de la pêche de la sardine et autres espèces au Maroc, les principaux armements locaux sont installés dans cette région. Il y a peu de temps encore, il s'agissait surtout de petite pêche côtière en pirogue. Par contre, les riches zones de remontées d'eaux profondes exercent une forte attraction sur les pêcheurs d'autres régions. Citons les chalutiers d'Europe méridionale, qui s'intéressent principalement aux espèces nobles telles que les sparidés; les pêcheurs japonais qui recherchent les mêmes espèces, ainsi que les encornets, poulpes et seiches; les pêcheurs d'Europe orientale, qui pêchent diverses espèces, notamment les espèces pélagiques telles que le maquereau et le chinchard et sont passés du chalut à la senne tournante; enfin, les pêcheurs de Scandinavie et d'Afrique du Sud, qui capturent les poissons pélagiques, en particulier les sardinelles, pour la fabrication de farine de poisson. Les flottes des pays de la région se sont développées; dans la zone tropicale, elles comptent de grands navires de pêche lointaine qui se rendent dans les eaux riches du nord, ainsi qu'au sud dans le courant de Benguela.

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Plusieurs des stocks de la région sont intensément exploités ou en voie de l'être. Au nombre des mesures d'aménagement nécessaires, figurent la collecte et l'analyse des données de base destinées à l'évaluation de l'état des stocks, la limitation du volume total de la pêche à un niveau approprié pour chaque stock, et la promotion d'une participation croissante des pays africains riverains à la pêche en haute-mer.

Il est donc clair que des arrangements bilatéraux et multilatéraux s'imposent entre les pays de la zone fortement peuplée mais à faible production halieutique, et ceux de la zone productive mais moins peuplée. Cela serait avantageux pour les deux groupes et stimulerait la coopération et le commerce intra-africains.

Los recursos del Atlántico centro-oriental están distribuidos en dos zonas. La zona septentrional, templada o subtropical, es una región donde la presencia de afloramientos de aguas frías determina una elevada producción de especies pelágicas, como sardina, alacha y machuelo, caballa y jurel, y de especies demersales, como los diversos espáridos, merluza y varias especies de cefalópodos. La zona tropical, aproximadamente desde Cabo Verde hacia el sur, es menos rica, aunque contiene gran variedad de especies.

La distribución de la población humana y de los mercados potenciales es muy desigual, concentrándose la mayor parte en la zona tropical, por lo que con excepción de la sardina y otras pescas de Marruecos, los naturales despliegan sus principales actividades en esta región. Hasta hace muy poco, la mayoría de ellas no han sido más que pequeñas de bajura, con canoas. Estas ricas zonas de afloramientos han representado un fuerte atractivo para los pescadores de fuera de la región, entre ellos, arrastreros del sur de Europa, interesados principalmente en especies de gran valor como los espáridos; pescadores japoneses, interesados en esas mismas especies y en el calamar, el pulpo y la jibia; pescadores de Europa oriental, que emplean artes de arrastre (y más tarde, de cerco de jareta) para capturar diversas especies, especialmente pelágicos, como caballa y jurel; y pescadores de Escandinavia y Sudáfrica dedicados a los peces pelágicos, especialmente alachas y machuelos para transformarlos en harina. Los países de la zona se han dedicado a mejorar sus flotas; las de algunos de los países tropicales cuentan ya con embarcaciones de grandes dimensiones y autonomía con las que pescan en las zonas más ricas situadas al norte y al sur de la corriente de Benguela.

Varias poblaciones de la región estan ya intensamente explotadas, o están a punto de serlo. Entre las medidas reguladoras necesarias figura la recogida y análisis de datos fundamentales para evaluar la situación de las poblaciones, la limitación de la actividad pesquera total hasta un grado que responda a las posibilidades de cada población y la mayor participación de los paises ribereños africanos en la pesca de altura.

Son necesarios acuerdos bilaterales o multilaterales entre los países que se encuentran en la zona de abundante población humana y escasa producción de pescado, y los países que se encuentran en la zona productiva, pero menos poblada. Estos acuerdos serían ventajosos para ambos grupos y estimularían el comercio y la cooperación intra-africanos.

THE eastern central Atlantic, in the sense used here, covers the area from the Straits of Gibraltar in the north to the mouth of the Zaire River in the south. Fisheries have existed in this area for a long time, including both local fisheries and fisheries by European countries, but the present pattern of fishing is of recent development. In 1958 the total catch in the area was around 400,000 tons (about half being accounted for by the Moroccan sardine fishery), but in little over a decade it has increased to 2.6 million tons in 1970. Much of this increase is due to the activities of long-range fleets from outside the region, although several African countries are rapidly developing their fisheries.

Clearly, although the fish resources are large, this rapid rate of expansion (doubling every 5 years) cannot be continued for long. Several stocks are already showing signs of too heavy exploitation, and management of these and several others is likely to be needed now or in the near future. At the same time African countries, particularly those around the Gulf of Guinea with large populations and a high demand for fish, are anxious to develop their own fisheries and to increase their share of the total catch.

The eastern central Atlantic thus provides a good example of the twin interlocking problems of development and management which are the topics of this meeting. It also illustrates well the complexities that can arise through differences in fish stocks, methods of fishing, and national demands for and uses of fish. This variety is probably greater off West Africa than anywhere else in the world. The fish stocks range from the large shoals of pelagic fish, often of a single species (such as the sardine in the north and sardinellas further south), to the complex tropical demersal communities of a hundred or more species. The fishing vessels range from primitive canoes to the most advanced freezer–trawler or factory mother-ship, and come from all parts of the world. Countries as far apart as Italy, USSR, Japan, and the United States all have major fisheries in the region.

Resources

The distribution and magnitude of fish resources are determined by physical and oceanographic characteristics of the region. Except for the tunas, most commercially valuable fish are distributed over or adjacent to the continental shelf. This is generally rather narrow, around 30 nautical miles (55 km) wide. In the Bissagos area, near 10°N, it widens to 110 nautical miles (200 km), but off Ivory Coast, Togo, and Dahomey the width is only some 10 nautical miles.

The most important oceanographic features are the upwelling areas on each side of the equatorial zone in which cool, nutrient-rich waters rise to the surface, giving rise to high primary production and hence rich fish resources. The extent and position of these upwelling areas vary with the seasons. Permanent upwelling occurs around the latitudes of the tropics of Cancer and Capricorn. In the northern winter the northern upwelling extends south to about 10°N, and in the summer it extends north to the Strait of Gibraltar. The southern upwelling zone normally extends well to the south of the region discussed here, and in the southern winter it moves north to around the equator. Minor upwelling also occurs seasonally in the Gulf of Guinea, from the Ivory Coast to Dahomey.

The richest parts of the region are therefore in the northern upwelling area, where stocks also differ from those farther south in containing fewer, mostly subtropical species. It is convenient to discuss this area, roughly north of Cape Verde (15°N), separately from the southern tropical area. The magnitude of the resources and the potential sustained harvest that can be taken from them have been estimated by a number of working groups. Detailed descriptions and evaluations of the resources are given in the reports of these groups (especially the CECAF Working Parties on Regulatory Measures for Demersal Stocks, and on Resources Evaluation), and other studies (including documents prepared for the Consultation on African Fisheries, Casablanca, May 1971, and two general studies, the Fish Resources of the Ocean, and the Atlas of the Living Resources of the Seas). In describing the resources it is also convenient to distinguish three types: bottom-living (demersal) animals (e.g. sea bream, croakers) mainly harvested by trawlers; coastal pelagic fish, living in mid-water, often in shoals which surface periodically (e.g. sardinella, mackerel), and are harvested by purse seines and mid-water trawls; and oceanic fish such as the tunas.

NORTHERN REGION

In the north the most important groups of demersal fish are the sea bream, hake, and cephalopods (octopus, squid, and cuttlefish). These, together with a variety of other species, could provide annual catches of half to three-quarters of a million tons.

The most important pelagic fish are the sardines in the north (off Morocco and Spanish Sahara), sardinellas in the transitional region between the tropical zone and the area of permanent upwelling, and mackerels and horsemackerels in the whole area. The potential of each of these groups seems roughly equal, with a possible total annual yield, including other less important groups such as scads and bluefish, in excess of 1.5 million tons. These fish are active and undertake considerable movements, both toward and away from the shore, and also parallel to the coast.

TROPICAL REGION

In the tropical zone the demersal resources are characterized by a large variety of fish species, of varying commercial value (croakers, threadfins, groupers, skates, etc.). In addition, pink shrimps, and a few other species provide highly valuable resources in inshore waters. The abundance of these resources varies from area to area, depending on the extent of the shelf, the duration of any seasonal upwelling, and for shrimps, run-off from rivers and the existence of brackish lagoon areas. Area differences are maintained by lack of marked migration or other movement of fish along the coast. The total potential annual yield is probably somewhat less than half a million tons, including around 15,000 tons of pink shrimps.

The pelagic fish are mainly sardinella, with mackerel and horsemackerel more abundant in areas of seasonal upwelling. With the exception of the flat sardinella, they appear to make appreciable movements along the coast, probably in response to changes in oceanographic and food conditions. Bonga is also locally important, especially close inshore in areas of low salinity water. There is evidence of important stocks of anchovy though so far no large-scale fishery for this species has developed. The total potential is probably slightly above that of the demersal stocks, i.e. about half a million tons per year.

OCEANIC STOCKS

The oceanic stocks of the greatest present importance are the tunas. Large individuals, as judged by catches of longline vessels, are found in all the warmer waters of the Atlantic (yellowfin and bigeye in the tropics, albacore and bluefin in subtropical and temperate waters), but the richest grounds for surface fisheries using purse seines or live bait, catching tropical species (particularly yellowfin and skipjack) are relatively close to the West African shelf in the areas of seasonal upwelling. The potential sustained harvest of tuna from the Atlantic is probably half a million tons annually, a larger proportion of which could come from the eastern central Atlantic.

Other oceanic resources, such as oceanic squids or myctophids, might provide substantially large catches, but techniques for their harvesting have not yet been developed in the area.

Demand for Fish

The demand for fish in West Africa over the decade has been estimated, based on the extrapolation of trends in income, and population growth (FAO 1971d). The results are summarized in Table 1 for the northern and southern zones separately, together with the potential fish yields, and the total human population estimated for 1970.

Several important features are clear from the table. First, there will be a substantial increase in demand in the next decade, but this would be within the capacity of the marine fish resources of the region to supply. Secondly, within this reasonably satisfactory situation, there is an uneven geographic distribution. The greater part of the demand is in the tropical area where the fish resources are relatively poor, whereas the rich fish stocks are adjacent to thinly populated areas. (The same wind system is responsible for the rich upwelling areas at sea and the dry desert on land.) The table also shows that despite the relative poverty of fish resources, the per capita consumption of fish *in the tropical zone is at least as high* as in the north. This is largely because in the forest zone along the coasts of the Gulf of Guinea animal production is difficult, and animal protein needs cannot be fully met by imported supplies of meat from the savannah areas farther north (Mali, Niger, northern Nigeria, Chad, and northern Cameroon).

TABLE 1. Present consumption (1970) and estimated future demand for fish, compared with the potential supply, in thousands of metric tons.

		Projected demand						
		1970		1975		1980		
Area	1970 population (*millions*)	Total	per capita	Total	per capita	Total	per captia	Potential catch
Gibraltar to 10°N	26	232	9.0	267	8.9	312	8.9	More than 2000
10°N to Zaire River	83	757	9.1	1008	10.6	1353	12.3	About 1000

This imbalance has given rise to a long history of international fish trade in the region. Traditionally the coastal countries bordering the tropical area have imported dried fish from the richest areas in the north (Canary Islands, Mauritania) and in the south (Angola) as well as from the inland fisheries of Africa (Mali, Chad); however, in the past direct north–south trade has been only a fraction of the total. The northern export trade, principally canned fish and fish meal, has been mainly from Morocco to Europe, while the Gulf of Guinea countries had also to import stockfish from northern Europe. This situation had become more marked with the development of long-range fisheries, since the bulk of their production is exported outside of the eastern central Atlantic area.

The pattern of demand strongly influences present development and future plans of African countries. Apart from specialized shrimp and tuna fisheries, development in the tropical countries is principally toward providing fish for home consumption, in local waters and by increased participation in the rich fisheries of the upwelling zones. Such countries as the Ivory Coast and Ghana have already started developing significant medium- to long-range fisheries and others (e.g. Nigeria) intend to do so. The northern countries are more interested in maximizing the economic benefits from the fish stocks off their shores, preferably by developing their own, export-oriented fisheries or failing this, from the licensing of foreign vesssels.

Fisheries of the Eastern Central Atlantic

The fisheries in the region may for the purposes of discussion be conveniently divided into three groups — local artisanal fisheries, African-based industrial scale fisheries and those of countries outside the region.

ARTISANAL FISHERIES

The oldest fishery is from canoes, widely used from Mauritania to Angola. In some countries canoe fishing is on a small scale, mainly at the part-time subsistence level. In others, canoe fishermen supply a large proportion of the total catch, e.g. an estimated 60,000 tons in Ghana. In Senegal, following motorization of canoes, better transport and distribution inland, landings have increased from 25,000 tons in 1950 and 80,000 tons in 1960 to 139,000 tons in 1970. The total number of canoes working along the whole West African coast is estimated between 30,000 and 40,000. Establishment of canoe fishing is helped by the simplicity of the equipment, low maintenance costs, suitability for crossing the surf, and large number of landing places which facilitates the distribution of catches. However, opportunities for development are restricted by the limited range of operations, and by the limits on the size and type of gear that the canoe crew can operate.

Steps are being taken to overcome these difficulties by the introduction of engines for the canoes, and of rather larger plank-built boats. For example, in the late 1950s a fleet of small open multipurpose boats of about 9 m were built in Ghana and introduced by a Government loan scheme to local fishermen. This scheme has not been entirely successful, often because the extra care and maintenance required for the more complicated equipment have not always been forthcoming. Also, operation of the larger boats requires a higher degree of business management skills, better supply of credit, etc. than the original canoes.

AFRICA-BASED INDUSTRIAL FISHERIES

Moroccan fisheries — The oldest industrial scale development is the Moroccan sardine fishery. This developed in the 1930s, catches increasing from 3000 tons in 1927 to 120,000 tons in 1950. The fleet had grown by 1950 to some 360 purse seiners some 15-m long and with engines of around 180 hp. Up to this time, nearly all the catch was canned for export to Europe, particularly France. The development was assisted by three factors: availability of large quantities of sardine and mackerel in nearby coastal waters; low local labor costs; easy, duty-free access to the French market.

After 1950 the sales of canned fish ceased to grow, although there were continued increases in total catch (with a peak of 250,000 tons in 1966) and in the fleet (now about 400 vessels). A growing proportion of the catch (now about half the total) is used for fish meal. Fish production, mostly from the purse seine fleet, accounts for about 8% of total Moroccan exports.

During the same period the Moroccan trawling industry developed, mainly for domestic consumption. Though the total catch by weight (29,000 tons in 1970, of which 7000 tons were horsemackerel, 4800 hake, 1900 sea bream, and 500 tons shrimp) is less than that of the purse seine fleet, the total value at first sale is about the same ($8 million US against $9 million US). The fleet consists of some 120 small trawlers about 18 m in length, and 3000 smaller vessels of which about 85% are motorized.

Gulf of Guinea: trawling — In the tropical region trawling on an industrial scale began after the second world war, in few cases (mostly abortive) by direct governmental initiative, but mostly on the initiative of owner-operators of small trawlers. The first vessels introduced were generally secondhand vessels from Europe, employing the type of gear normal in their place of origin and with which their alien deck officers were familiar. Trawling started in the Congo (1948) and in the early 1950s in Cameroon, Ivory Coast, Ghana, Liberia, Nigeria, Senegal, Sierra Leone, and Zaire, and finally extended to almost all the coastal countries, as soon as port facilities, ice supply, maintenance facilities, and product distribution permitted.

Because historical statistics are rather incomplete and in view of the frequent failures and bankruptcies observed during the initial period, it is not easy to follow precisely the development of local fleets of trawlers between Mauritania and Zaire. However, it is estimated that in 1955, 25 trawlers were in operation, in 1960 about 150 vessels, and some 250 in 1970 (excluding 140–200 small multipurpose boats operated in Ghana by artisanal fishermen). The most active ports for nearshore trawling are now Abidjan (16,000 tons), Douala (14,000 tons), Matadi (13,000 tons), Lagos (10,000 tons), Pointe-Noire (5000–9000 tons), and Tema (5000 tons).

During the early stages of these fisheries, almost all the successful boats were rather small (up to 20 m and 250 hp) vessels operating in inshore waters in the vicinity of the landing ports. Later, in countries where the fishery was developing steadily (e.g. Ivory Coast, Ghana, Cameroon), larger vessels (30–45 m) with more complex machinery and higher operation costs were progressively added for the purpose of exploiting more distant and less exploited fishing grounds.

Almost everywhere, efforts have been made to replace progressively the alien officers and fishing owners with local people. Training schools have been established in Ghana, Ivory Coast, and Nigeria, but local personnel with sufficient knowledge of navigation, fishing operations, and fleet management is still largely inadequate.

During the initial phase of development, fishing was mainly close to the ports. Progressively, all the inshore waters (from 10 to 40 m), which are the richest, have been exploited. Even now the offshore grounds (70–120 m) are not usually visited throughout the year, but mainly during the upwelling season when good catches of sea bream are obtained. These grounds are distinct from those visited by long-distance trawlers coming from non-African countries which fish on the offshore grounds between latitude 10° and 30°N. Therefore, there is not much overlapping in the exploitation by the two types of fleet. However, in some countries, e.g. Nigeria, Liberia, Sierre Leone, and Ghana, the landing of cheap frozen fish from long-distance trawlers fishing in the north has sometimes had an adverse effect on development of the local trawl fisheries. In addition to developing trawling off their own coasts, some of the countries in the Gulf of Guinea have their own medium- to long-range fleets operating in richer waters to the south and north. A number of 30–40 m vessels are operated by the Ivory Coast, while even larger vessels (up to 70–90 m) are, after an initial period of difficulties, operated by Government and private owners in Ghana. Two long-range vessels (60 m) were run by a Nigerian company, but the long-range operation was stopped because of inadequate local facilities for boat maintenance and repairs.

More recently, following the discovery of good grounds for the pink shrimp, shrimp trawling mainly for export to the USA, Japan, and Europe has been introduced. The vessels are either converted fish trawlers or new boats specially designed for that type of fishing. Most of the vessels are double-rigged according to the Gulf of Mexico design, of around 25 m and 300 hp. Shrimp fishing started in Nigeria in 1965 where the largest grounds were identified (off the Niger Delta and Calabar Region) and then was introduced to Senegal (1966), Ivory Coast, Cameroon, Gabon (1969), Liberia, Ghana (1970), and finally in Gambia, Togo, and Dahomey. At present most of the stocks located from Senegal to the Zaire River are exploited by about 100 vessels landing mainly in Dakar (3000 tons), Lagos (2500 tons), Monrovia (1300 tons), and Abidjan (1200 tons).

Gulf of Guinea: purse seining — Purse seining with medium-size boats has been introduced, first in the late 1950s in the Congo and Ivory Coast, in the early 1960s in Ghana and Senegal, and later in Mauritania. Its introduction is now being considered in Zaire. The first boats (15–20 m), gear, and fishing methods introduced in the Congo and Ivory Coast were those employed by the Portuguese fishermen in the sardine fishery off Morocco. Progressively, sizes of boats and purse seines have been increased and new techniques for fishing (power block) and preserving the catches (refrigerated sea water) have been introduced, but they are not yet widespread. In Ghana, purse seining is carried out mainly by smaller open multipurpose boats built locally. In the Ivory Coast, larger boats (20–25 m) of traditional Spanish seiner design built locally are operated.

This fishery is restricted to the three zones of seasonal upwelling where supplies of sardinella are available in quantity. Fishing is carried out mainly in inshore waters, usually less than 40 m. In Senegal, some seasonal fishing operations take place in deeper waters (60–80 m) south of Cape Verde. It is only in the Ivory Coast that the medium-size purse seiners go fishing outside the continental shelf bordering the country; as local stocks have become inadequate to support the increasing effort, local purse seiners have progressively gone fishing off Ghana where they have sometimes landed their catches, and they have recently started to fish off Sierra Leone. In Senegal and the Congo, where development is hampered by marketing and distribution limitations, vessels perform shorter trips close to their home port.

In 1971 the situation of the fisheries was as follows:

Country	No. medium-size purse seiners	Annual landings
Mauritania	4	?
Senegal	4–5	14,000 tons
Ivory Coast	35	36,000 tons
Ghana	140 multipurpose boats (15–25 m)	18,000 tons
Congo	3	2,400 tons

NONLOCAL FISHERIES

The existence of fleets from outside the region working off northwest Africa is no new phenomenon. For example, the treaty signed in 1903 between France and Spain recognized the right of Spanish fishermen to fish in Mauritanian waters. Nor are these long-range operations necessarily dependent on large, technically advanced vessels. A valuable lobster fishery off the shores of Spanish Sahara and Mauritania was carried out by sailing boats from Brittany, particularly from the port of Camaret which before the second world war specialized almost entirely in that fishery. However, the great rise in long-range fishing, as in all parts of the world, was made possible by the development of freezing and processing at sea, which greatly increased the time which the vessels could stay at sea, and their independence of local shore facilities. The effect on catches off west and northwest Africa is shown in Table 2.

TABLE 2. Catches by locally based and long-distance vessels in the eastern central Atlantic, in thousands of metric tons and by percentage.

		1958	1961	1964	1967	1970
Locally based[a]	10^3 tons	490	550	570	750	890
	%	86	77	50	49	34
Long-distance[b]	10^3 tons	80	160	570	780	1710
	%	14	23	50	51	66

[a] Includes estimates of the Spanish catches landed in the Canary Islands.

[b] Excludes catches of long-range vessels based in the region, e.g. Ghanaian vessels fishing off Mauritania.

Some of these foreign flag registered vessels are on charter to fishing companies in countries of the region, e.g. Nigeria and Cameroon. The arrangement — for the duration of the charter, usually 1 year — is that in return for a monthly charter fee paid in foreign exchange to the owner of the vessel, the vessel together with key members of its crew are put at the disposal of the local company. In practice, most companies insist on a proviso in the agreement that a stated minimum quantity and quality of fish will be landed by the vessel in a given time. In Nigeria the chartered vessel must also accept Nigerians for training at all levels, so that in future charters the local company can reduce the alien staff component and build up competent local staff for that type of fishing.

Four major groups of nonlocal fisheries can be distinguished: trawl fisheries, mainly from southern European countries and Japan for high-valued demersal fish; fisheries by the long-range fleets of USSR and other eastern European countries, initially only by trawlers mainly looking for pelagic species; recent fish-meal fisheries, using fleets of purse seiners supplying fish to large factory ships; tuna fisheries.

Western European and Japanese trawl fisheries — Fisheries in the eastern central Atlantic area by countries of southern and western Europe have been natural extensions of fisheries in their home waters. Soon after the beginning of the century, steam trawlers, preserving their catch with ice from Spain, Portugal, and even England and Wales, were visiting Moroccan and Spanish Sahara waters, particularly for hake and sole. Following development of freezer trawlers other Mediterranean countries, notably Italy and Greece, joined the fishery which progressively extended farther south off Mauritania, Senegal, and Gambia. These more southern countries had less difficulty in marketing all the catch than, for example, French fishermen, since the species caught were more familiar and acceptable in their domestic markets. Catches by European-based trawlers rose rapidly in the early 1960s, but since then falling catch rates have slowed down their development (Table 3).

TABLE 3. Catches of demersal fish by vessels from Western Europe and Mediterranean countries off northwest Africa, in thousands of metric tons.

	1958	1961	1964	1967	1970
Greece	?	14.5	21.0	31.6	33.3
Israel	–	–	0.8	2.3	1.2
Italy	5.9	11.8	37.6	69.4	62.9
Portugal	43.8	52.8	47.4	39.8	36.5[a]
Spain[b]	120.0[a]	130.0[a]	155.0	179.4	153.1

[a] FAO estimate.

[b] Includes pelagic fish and landings on the Canary Islands.

In addition to the trawl fisheries, sardine fishermen from France and Spain are visiting the waters off Morocco and Spanish Sahara. Catches have never been great, amounting to some 15,000 tons in 1965 and 42,000 tons in 1970.

The trawl fisheries of Japan (and recently the Republic of Korea) may be conveniently grouped with the southern European freezer–trawler operations because of the general similarity in the species sought. Like the European vessels, the Japanese trawlers are mainly interested in the higher-valued species such as sea bream, but concentrate much more than the Europeans (except Spanish) on cephalopods (Table 4).

After a rapid development following the start of Japanese fishing in 1959, expansion has now slowed down. This has been due to Japanese Government limitation of licences (in 1967, 70 vessels, mostly large stern trawlers, were licensed to fish in the whole eastern Atlantic, including the area south of the Zaire River), added to difficulties of falling catch rates and the extended jurisdiction recently

TABLE 4. Catches by Japanese trawlers off northwest Africa, in thousands of metric tons.[a]

	1964	1965	1966	1967	1968	1969	1970
Sea bream	11.4	15.0	19.4	23.6	16.2	21.1	16.9
Cuttlefish	14.4	31.1	22.1	31.6	29.4	24.1	13.7
Octopus	6.7	26.5	25.7	53.8	72.9	46.2	50.9
Squids	2.7	5.8	4.0	11.5	6.7	5.6	5.0

[a] Source 1964–69: Report of CECAF Working Party on Regulatory Measures for Demersal Stocks; 1970: FAO Yearbook of Fishery Statistics.

claimed by some coastal states. The fleet is largely based on Las Palmas in the Canary Islands, from which most of the catch is shipped to Japan, though some fish is exported to Mediterranean countries and also sold to West African states (e.g. Ghana and Nigeria), either shipped from Las Palmas or by direct landings in African ports.

Eastern European fishing — The growth of fishing by USSR, Poland, and other eastern European countries in the eastern central Atlantic is part of a wider pattern in which these countries have built up long-distance fisheries in the North Atlantic (and in the case of the USSR throughout the world). Until recently, fishing has been aimed at fish for direct human consumption (though the large vessels have equipment for converting waste and whole fish to fish meal). Their domestic markets have allowed them to concentrate on lower priced but more abundant species than those sought by the western European fleets, particularly mackerel, horsemackerel and and now sardinella.

The first exploratory surveys by the USSR were made in 1957, and in the following years catches by the USSR rapidly grew to over 15,000 tons in 1964. After 1964 catches declined for a few years, but grew rapidly again after 1968 to nearly 800,000 tons in 1971. This latter increase was associated with development of purse seining by USSR vessels. They first used this method in the eastern central Atlantic in 1969, and by 1971 approximately half the total USSR catch in the region was taken with purse seines. Catches in recent years are given in Table 5.

TABLE 5. Catches in the eastern central Atlantic by eastern European vessels, in thousands of metric tons.

	1964	1967	1970	1971
Bulgaria	0.9	8.0	20.0	9.4
German Democratic Republic	–	13.0	28.9	33.0
Poland	14.7	45.8	31.2	30.0
Romania	0.8	8.9	4.7	3.3
USSR	163.8	153.5	612.5	789.8

Over the last decade there have been changes in the species composition of the catches (Table 6, from Razniewski et al. 1971). These changes, away from truly demersal fish and toward horsemackerel, mackerel, and sardinella, have been due partly to changes in the relative abundance of different species, and partly to changes in gear. Initially only bottom trawls were used, then both mid-water and bottom trawls with progressively more midpelagic trawling, and in the last couple of years, also purse seines.

Fish-meal Fisheries — At the end of 1969, at about the same time as the USSR purse-seine fishery began, another group of purse-seine fleets started operating in the region. These were vessels from Scandinavian countries and South Africa fishing for fish meal; the processing was done mainly in large factory ships (mostly converted whale factory ships), though there were a couple of self-contained catcher–factory vessels. These fleets operated mainly between 12° and 23°N, and the catches, which varied with the season and location of fishing operations, have comprised mainly sardinella, horsemackerel, and mackerel. Estimates of annual catches are given in Table 7.

TABLE 7. Catches in the eastern central Atlantic by long-distance industrial fisheries, in thousands of metric tons.

	1969	1970	1971
Scandinavian vessels	0	96	200
South African vessels	80–100	255–275	144
Independent vessels	0	36	0

TABLE 6. Species composition of Polish catches during 1965–69.

	1965	1966	1967	1968	1969
Total catch in thousands of tons	24.6	40.7	44.3	32.9	44.5
			Percentage		
Chub mackerel	13.8	18.3	19.8	25.1	35.8
Horsemackerel and scads	23.6	15.4	17.8	15.1	18.5
Sparidae (sea bream)	15.8	6.7	4.6	4.6	1.7
Other edible fish	44.8	47.2	26.8	19.0	13.5
Fish for fish meal	2.0	12.4	31.0	36.2	30.5

TABLE 8. Catches of tuna by longline gear in the Atlantic, in thousands of metric tons.

	1957	1959	1961	1963	1965	1967	1969
Yellowfin							
Japan	10.4	43.9	38.7	37.7	36.6	12.8	9.8
Republic of Korea	–	–	–	–	–	–	2.4
Taiwan	–	–	–	0.4	0.1	2.3	10.0
Albacore							
Japan	0.6	6.2	7.4	29.7	42.3	12.5	11.0
Republic of Korea	–	–	–	–	1.0	10.3	7.8
Taiwan	–	–	–	–	0.1	1.8	11.5
Bigeye							
Japan	0.4	2.0	11.2	11.6	32.5	8.8	10.6
Bluefin							
Japan	0.1	0.3	0.6	7.8	9.6	0.9	0.8

After a peak in 1970, the amount of fishing and the catches dropped partly following extension of the limits of fishery jurisdiction by some countries and the departure of some fleets. Agreements have been made, or are in progress, to allow some fishing under licence from certain coastal states.

Tuna Fishing — The tuna fisheries are carried out by two distinct groups of gear — longlines, working at times at some depth below the surface, and the surface fishing gear such as purse seines or pole-and-line. Unlike the fish exploited by the previous groups of gears which are confined to the areas over or close to the continental shelves, tuna are truly oceanic fish, and the fishery, particularly the longline fishery, is oceanic. Thus, the longline fishery in the eastern central Atlantic cannot be separated from the fishery in other parts of the Atlantic — indeed, a vessel may fish in several parts of the Atlantic in the same voyage.

For the first few years after it began in 1957 the longline fishery was purely Japanese, but in the last decade vessels from the Republic of Korea and from Taiwan have entered the fishery. The total longline tuna catches in the Atlantic are given in Table 8. This shows the change in species composition, in the early 1960s, away from yellowfin and toward albacore, largely due to a decrease in catch rates of the former species, and to resulting change in the distribution of fishing. Not all the catches set out in Table 8 were taken in the Eastern Central Atlantic. Most of the cooler-water species (albacore and bluefin) were probably taken north or south of the region. For the tropical species (yellowfin and bigeye), fishing is concentrated toward the eastern half of the ocean, and most of the longline catches were taken in the present region.

Large-scale surface fishing for tuna started at about the same time as longlining (about 1954), with the arrival of small French bait boats to work out of Dakar in the winter. Since these small vessels preserved their catches on ice, and so could not make long voyages and were dependent on local bases, they were not, in the strictest sense, long-distance vessels. Since 1954 tuna fishing has spread as far south as Angola; the position and timing of the fishing seasons tend to correspond to those of seasonal coastal upwelling (i.e. Mauritania–Sierra Leone; Ivory Coast–Dahomey; and Gabon–Angola). More recently, another important offshore ground has been found around the equator and the Greenwich meridian. The vessels have increased in size (most now freezing their catch) and purse seiners have overtaken bait boats in performance. Since 1967 a United States fleet of large purse seiners, mostly from California, has joined the West African tuna fishery, moving out of the eastern Pacific in the second half of the year when the yellow fin quota has been filled. The bulk of the catch is taken by France, Spain, USA, and Japan, but a number of African countries, notably Senegal and the Ivory Coast, are developing their own tuna fleets. The recent development of the surface tuna fishery is given in Table 9.

TABLE 9. Tuna catches off West Africa by surface fisheries, in thousands of metric tons.

	1963	1965	1967	1969	1971
Yellowfin and bigeye[a]	28.5	23.7	36.4	61.8	43.9
Skipjack	18.4	41.0	37.9	42.6	78.8

[a] Small yellowfin and bigeye are often confused in the catches.

Present Knowledge of Potentials and State of Exploitation

Generally speaking, the resources are well identified and located. Only a few exploratory surveys — which for some species would require some development of fishing gear suitable for their capture — are still needed, e.g. for the anchovy in the whole area, and for mackerel, horse-mackerel, and perhaps squid in the Gulf of Guinea. Poor knowledge of stock indentification and patterns of migrations and intermingling hampers stock assessment, particularly for coastal pelagic species which migrate

TABLE 10. State of exploitation of the major stocks in West Africa.

<table>
<tr><th>Heavily exploited (in urgent need of management)</th><th>Moderately exploited</th><th>Little exploited</th><th>Unexploited</th></tr>
<tr><td colspan="4"><i>Oceanic areas</i></td></tr>
<tr><td>Yellowfin tuna</td><td>Skipjack
Bigeye tuna</td><td>Skipjack
Bonitos</td><td></td></tr>
<tr><td colspan="4"><i>Northern subtropical region</i></td></tr>
<tr><td>Hake
Sea bream
Cuttlefish
Squid
Spiny lobster</td><td>Octopus
Moroccan sardine
Sardinella
Horsemackerel
Mackerel
Bluefish</td><td>Anchovy</td><td></td></tr>
<tr><td colspan="4"><i>Southern tropical region</i></td></tr>
<tr><td>Inshore demersal stocks in some areas (e.g. Ivory Coast, Nigeria, Cameroon, Congo)</td><td>Inshore demersal stocks in other areas (e.g. Senegal, Guinea, Sierra Leone)</td><td>Offshore demersal stocks in the Gulf of Guinea</td><td></td></tr>
<tr><td></td><td><i>Brachydeuterus auritus</i></td><td></td><td></td></tr>
<tr><td>Pink shrimp</td><td>Pink shrimp</td><td>Littoral shrimp</td><td>Squid</td></tr>
<tr><td>Flat and round sardinella (Ivory Coast, Ghana)</td><td colspan="2">Deep water prawn</td><td></td></tr>
<tr><td></td><td>Bonga</td><td>Mackerel
Horsemackerel</td><td>Anchovy
Small tuna</td></tr>
<tr><td></td><td colspan="2">Flat and round sardinella (Gabon, Congo, Angola)</td><td></td></tr>
</table>

seasonally in transitional areas of seasonal upwelling (Spanish Sahara to Sierra Leone and Gabon to Angola), but the number of distinct stocks present in each area is not known.

Table 10 gives in schematic form the present knowledge on the state of exploitation of the main stocks in the eastern central Atlantic. Although several assessments are already available they do not always concern the largest stocks. For instance, the magnitude of the coastal pelagic stocks occurring in the subtropical area (Moroccan sardine) and in the areas of seasonal upwelling (sardinella, mackerel, horsemackerel, and scads), which now make up more than 50% of the total catches in the CECAF area, is not precisely known. The situation is more satisfactory in the Gulf of Guinea as a whole. This unbalanced situation has two different origins: more work in the field of stock assessment has been done in the Gulf of Guinea, where the resources are less important; due to the rapid and recent development of exploitation in the north, the mechanisms for collecting data are not yet fully operational and problems of compilation are more difficult because the stocks are fished by a greater number of countries.

Stock assessment has been carried out by fisheries laboratories of the fishing countries operating in the area, as well as by a number of Working Groups on resources evaluation established by CECAF[2] and ICCAT[3]. Reviews of the available stock assessments are given in the reports of these Groups.

Some individual stocks have been appraised, at least approximately. These are: yellowfin in the whole Atlantic; hake, octopus, cuttlefish, and squid in the subtropical area; flat and round sardinella off Ivory Coast and Ghana; as well as some local stocks of croakers and pink shrimps in the Congo, Nigeria, Ivory Coast, and Senegal. In two other cases the evaluations dealt with a group of species belonging to the same family (sea bream in the subtropical area) or to the same fish community exploited simultaneously (the inshore demersal community on muddy bottoms occurring all along the Gulf of Guinea).

In those cases it was not possible to deal with each species separately because, for the former, data available could not be broken down by species, and for the latter, because of the great number of species belonging to tropical communities (taking into account the expertise and means locally available). With regard to the inshore demersal and the shrimp resources found in the Gulf of Guinea, quantitative assessments are only available for a few local stocks, but it should be possible to extrapolate the existing estimates to the other stocks in the Gulf of Guinea where no estimates on their magnitude are available so far.

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[2] FAO Fishery Committee for the Eastern Central Atlantic.

[3] International Commission for the Conservation of Atlantic Tunas.

The situation is much less satisfactory for the coastal pelagic stocks in the northern and southern upwelling area. Although stock assessment work has been carried out on these stocks, mainly by local laboratories in Congo and Senegal, so far it mainly concerns only part of the stocks, and is therefore of limited practical value. This situation is unsatisfactory for the stocks of the northern area, where fishing by pelagic trawlers and purse seiners has developed rapidly. If it is not possible to succeed promptly in the collection and compilation of the minimum data required for such appraisals from components of the fishery, danger of overexploitation and overcapitalization will be serious, as resources will be overfished before their potential can be estimated.

The potential of the Moroccan sardine is also unknown, or at least is not known with the required accuracy. However, it is believed that it is not yet fully exploited. The maximum observed in 1966-67 in the Moroccan landings seems to be due to particularly favorable conditions either in recruitment or in availability of the fish in relation to environmental conditions.

Several models or methods have been applied. The best results — from a practical point of view — were obtained by analyzing the experimental relations between the fishing effort on the one hand and the total catches and catch per unit effort (cpue) on the other. Maximum potentials, under current conditions of fishing, were obtained in this way for hake, sparids, and cephalopods in the north as well as for flat sardinella and inshore demersal stocks occurring off the Ivory Coast. The estimates thus obtained are most useful for planning the development of corresponding fisheries. However, when a further increase in annual production can be expected through a change of the age at first capture, these results need to be refined. Some quantitative studies on the effect of selectivity on production have been made, for instance, for hake and sea bream in the northern upwelling area and for a small number of demersal species of the inshore demersal stocks of the tropical area. In the latter these studies are made difficult by the great number of species involved. Practical application of such findings is even more intricate, because of appreciable differences between their biological characteristics as well as their commercial value (which itself varies according to local changes in the demand for fish).

Some semiquantitative methods have also been successfully applied. For instance, a rough estimate of the potential of pink shrimp on the Ivorian shelf has been obtained by comparing the maximum fishing intensity that similar grounds and stocks (Florida, Senegal) can support and their maximum production. This preliminary estimate, obtained before data from the starting exploitation could have been collected, has made it possible to slow down the rate of investment, which otherwise within 1 year would have overshot the potential.

For some stocks, e.g. yellowfin tuna and certain species of croakers in the Congo, Nigeria, and the Ivory Coast, the complete yield equation has been applied. Although such models are useful for single-species stocks, their application to demersal stocks in a tropical area such as the Gulf of Guinea is difficult because of the great variety of species present and the limited expertise and means locally available. However, a methodology has been especially developed for estimating the dynamic parameters of some tropical fishes (i.e. age determination). These studies have improved our knowledge of the bionomics of tropical fish populations in that part of the world, including the rate of energy turnover (growth, natural mortality).

Quantitative acoustic methods have been recently applied, and some direct abundance estimates of anchovy and mackerel were obtained off Ghana and the Ivory Coast.

Management — Current Needs and Practice

Several stocks, e.g. Table 10, sea bream, yellowfin tuna, and some inshore typical demersal stocks, are heavily fished. These stocks and their fisheries would benefit from appropriate management measures. However, in any international fishery, such as most of those off West Africa, management action is effective only if it is taken by all, or the large majority, of those exploiting the stock. Thus, management of any stock, except those which remain within the jurisdiction of a single country, requires some regional machinery to coordinate action. In the region two bodies are available to provide this machinery — the International Commission for the Conservation of Atlantic Tuna (ICCAT) and the FAO Fishery Commission for the Eastern Central Atlantic (CECAF).

ICCAT is an independent, treaty-based body, which held its first meeting in Rome in 1969 and has some 12 member countries including most of those with significant tuna catches, though several African countries with good possibilities of developing their own tuna fisheries are not yet members. As its title implies, the terms of reference of ICCAT are directed specifically towards conservation and management. It has concentrated on setting up the basic groundwork for management action — arrangements for tabulation of statistics, carrying out stock assessments, etc. This preliminary phase is now coming to an end, with the establishment of effective working arrangements for the collection and analysis of data. This analysis, particularly the results of the working party on stock assessment of yellowfin tuna which met in Abidjan in June 1972, shows that these stocks are or soon will be in need of management. It is to be expected that the Commission will give serious attention to possible management measures at its next meetings.

CECAF, which is a subsidiary body of FAO and whose 27 members include nearly all countries with any interest in the fisheries of the area, has much broader terms of references, including all aspects of fishery development and management. It held its first session in Accra, Ghana, in 1969. Like ICCAT, much of its early work was concerned with laying a foundation for future substantive action, i.e. the collection of statistics and assessment of the resources. Following its second session at Casablanca in 1971, at which the scientific reports clearly showed that some stocks were heavily fished, CECAF set up a Subcommittee on Implementation of Management Measures. This met in Rome in June 1971, and recommended the use of larger meshes (70 mm) when fishing for hake and sea bream, as well as setting out details on such matters as how the mesh should be measured, proportion of catches of other species, etc. It is hoped that these measures will be endorsed by countries and soon put into effect. The subcommittee also emphasized the need to consider for certain stocks more stringent measures such as controls on the total amount of fishing, which were discussed during the third session of CECAF in December 1972.

International arrangements for managing fisheries have thus been moving forward at a pace which, in comparison with the rate at which management was introduced in other areas (North Atlantic, North Pacific) with an earlier history of heavy international exploitation, can be considered as satisfactory — though it must be acknowledged that the pace of international fishery development is much faster in this area than it was generally in the North Atlantic. However, because of the need for preparatory work, and the short time the appropriate bodies have been in existence, no internationally agreed measures are yet in force.

For fisheries wholly within single national jurisdiction, management measures can and should be applied on a national basis. Such include some lobster fisheries, many of the inshore tropical demersal (including shrimp) fisheries, as well as a few pelagic fisheries (e.g. for bonga). As many demersal species in the inshore communities appear to perform migrations of only limited range, their condition in any particular area depends to a large extent on the local conditions of exploitation. In addition, the continental shelf in the CECAF area is most often narrow, and inshore demersal stocks are often within the territorial waters of the bordering countries. As a first approximation, national home fisheries may then be considered as distinct. Several of these fisheries, mainly for inshore demersal stocks of fish and shrimp, would already benefit from mesh size regulations and limitation of fishing. In some countries legislation on mesh size has been promulgated, e.g. Nigeria. Licence schemes also exist in some countries, e.g. Ivory Coast, Senegal, and Nigeria, although their main objective is not always directed toward limiting the rate of exploitation. For some stocks the assessments available are precise enough for specific quantitative advice on the effect of particular management measures to be given. In such cases, regulatory measures should be enforced for the better management of national fisheries. For several other areas, however, the existing analyses describe the state of the stocks only in general terms, and they need to be refined. Comparison through international contacts of the potentials and rates of exploitation in various regions of the Gulf of Guinea where fish production is to a large extent similar would certainly help in generating the scientific information required for better managment of national fisheries.

Discussion

Up to the present the various groups of countries have conducted their operations independently. There has been good contact between scientists. At the beginning this was largely concerned with descriptive studies of the environment, inventories of available resources, and biology and life histories of fish and other animals in the area. Only recently have joint international studies been made dealing with the magnitude of resources and current effects of fishing. Virtually nothing has been done to coordinate development plans or management measures of the different countries.

This independence has been possible as long as fish stocks are not limiting, and the magnitude of the catch of one country has little effect on the possible catch that can be taken by another country. For many stocks, this is no longer true, and countries fishing these stocks must take into account the present and likely future activities of all other countries exploiting the same stock. The number of stocks for which this is true is likely to increase. The demand for fish and the technical and economic abilities to satisfy this demand will continue to increase, so that the capacity of the fleets working off West Africa will also expand.

Certainly, the relatively highly populated countries around the Gulf of Guinea hope for continued expansion in their fisheries, including a necessary extension of their activities to the richer waters to the north and south. Equally, the countries off whose coasts these rich resources occur will want to enjoy a greater share of the economic or other benefits, even if they do not plan to use the fish for internal consumption.

The non-African countries, taken as a whole, may also be expected to increase their interest in these fisheries, although the balance between countries may change. For example, a continuation of falling catch rates and increasing labor and other costs is likely to cause a stabilization, or even a decrease, in the participation of vessels from southern Europe. On the other hand, other countries will probably reach the stage of development where adequate technology and available financing, plus low labor costs and a large potential market, favor the growth of a large fishing industry, including long-range operations. An obvious example, in relation to the eastern central Atlantic, is Brazil, which is closer to the rich areas off northwest Africa than many of the non-African countries currently fishing there, and has most of the qualifications suggested above as conducive to the growth of long-range fishing.

There will therefore be increasing conflict between competing users of the same resources, as well as increasing need for each user (even a sole user) to take into account the limits set by the productivity of the resource. The changing patterns of fishery jurisdiction, both of unilateral extensions of national limits that have been recently declared, and the possible outcome of the forthcoming UN Conference on the Law of the Sea, will clearly affect the issue of these conflicts. However, whatever the pattern of jurisdiction, such changes cannot remove all possible conflicts. Many of the fish species concerned, e.g. coastal pelagic species in the northern transitional area, make long movements that cross the lines between national jurisdictions or possibly extend into areas beyond any national jurisdiction. Also, no changes in jurisdiction can alter the basic fact that the demand for the fish of many stocks, and the technical capacity for fulfilling the demand, now exceeds the biological capacity of the resource.

Fortunately the requirements and objectives of different countries are not always exactly the same, and are in part complementary rather than conflicting. The greatest need of the African countries of the tropical zone is for improved protein supplies, while the countries near the upwelling zones are more anxious for more general economic benefits. The fish that are favored by the western European (and Japanese) markets are generally the higher-valued types (especially tuna, shrimp, fish fillets) rather than the species of lower value (but still of high protein content) needed in Africa. Equally, the potential inputs to the fishery are different — the advanced technology, expertise and capital of the developed countries as against the local ports and other facilities and low labor costs of African countries.

There is therefore a good opportunity for reducing conflicts and increasing the effectiveness of each country's operations through closer collaboration between all countries with fishery interests in the region. This might take the form of a flow of technical assistance and investment into African countries from outside; further increases (up to the limit set by the capacity of each resource) in catches, particularly in rich areas of the upwelling zone; increased economic participation by coastal countries; a flow of fish from this zone, with more valuable species going to richer countries (so that local cash returns are greatest) and less valuable to the large African populations of the tropical zone.

The exact pattern would probably depend on the individual needs of each country. Thus, it might be a matter of fine economic judgement whether it would be more advantageous for, e.g. Cameroon to engage in long-distance fishing off, for instance, Mauritania, which might include a licence fee or other arrangement (e.g. joint fishing company, importation of additional fish products, or any other trade arrangement with Mauritania, as well as capital and managerial skill to initiate and operate the fishery), or to use these resources of men and capital in some other activity whose output might be used to pay for fish imports. Mauritania itself would have to make a similar judgement as to the desirability of merely enjoying licence fees, or of taking a more or less active and direct part in the fishery itself. As another example, Nigeria might arrange to engage in long-distance fishing in waters over which Senegal has declared exclusive or sovereign rights, in return for granting fish caught by Senegal easy access to the Nigerian market. Because of Nigeria's size, her demand for fish can accommodate both the products of a sizable long-range fishery of her own and considerable imports of fish from Senegal, fish which she would have had to import anyway. Senegal, on the other hand, produces more fish than required in her local market and is searching for external markets.

Many of the discussions and negotiations concerning trade, technical assistance, etc., can and should be carried out on a direct bilateral basis. However, a broader forum for regional discussions is desirable for several specific purposes (for example, exchange of research data and results, expecially in stock evaluation; coordinated planning and inter-regional trade). This is provided by the regional activities of FAO. The Fisheries Committee for the Eastern Central Atlantic (CECAF) provides an opportunity for general regional discussions and, through its working groups, for more specific and detailed studies of particular subjects. While the activities of CECAF are limited, partly by finance, to such general coordinating functions, it is expected that a more positive approach to regional problems and their solution will be provided by the Regional Fishery Development Project supported by the United Nations Development Programme, which, it is hoped, will start operations on a limited basis in 1973.

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Fisheries Planning to Meet Economic and Social Objectives with Special Reference to Countries Bordering the Eastern Central Atlantic[1]

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Planning responsibilities for fisheries should be entrusted to specially trained staff, not to economic and agricultural planners or even to fishery specialists with a technical, scientific, or general administrative background. Characteristics of fishery resources ("invisibility," mobility, and nonexistence of ownership rights) and of fish production (the large range of input/output combinations, technical and managerial requirements, fishing labor remuneration, and fish utilization) elevate such essential features of planning as inventory-taking and supply- and demand-projecting to an "art," which a planner unfamiliar with fisheries cannot be expected to have mastered. Fisheries specialists lack the know-how for selecting projects, and their record in planning is generally no better than that of nonspecialists.

Basic techniques of sectoral planning are summarized, and the methods of adjusting them to overall economic and social plans are described. Examples relating to countries bordering the eastern central Atlantic are presented, listing the types of questions planners might raise in initiating or evaluating programs.

Two proposals for improving fisheries development planning are mentioned — workshops on fisheries planning; and appointment of fisheries planning experts to give advice, set up planning units, and train counterpart personnel.

La responsabilité de la planification des pêches devrait être confiée à du personnel spécialement formé et non aux planificateurs économiques et agricoles, ni même aux spécialistes de la pêche ayant une formation technique, scientifique ou administrative générale. Les caractéristiques des ressources halieutiques – notamment leur "invisibilité," leur mobilité et l'inexistence de droits de propriété – et de la production ichtyologique – par exemple la grande diversité des combinaisons input/output, les besoins techniques et en matière de gestion, la rémunération des travailleurs de la pêche et l'utilisation du poisson – élèvent les fonctions essentielles de la planification (telles que la réalisation d'inventaires et de projections de l'offre et de la demande) au niveau d'un "art" dont on ne saurait attendre qu'il soit maîtrisé par un planificateur peu familiarisé avec la pêche. Les spécialistes de la pêche ne possèdent pas les connaissances voulues pour choisir les projets et, en matière de planification, ils ne sont en général pas plus compétents que les nonspécialistes.

L'auteur expose succinctement les techniques fondamentales de la planification sectorielle et décrit la méthode à appliquer pour les ajuster en fonction des plans économiques et sociaux d'ensemble. Il donne des exemples concernant des pays riverains de l'Atlantique centre-est et indique les types de questions que les planificateurs pourraient poser lors de la mise en route ou de l'évaluation des programmes.

Deux propositions sont formulées pour améliorer la planification du développement des pêches. La première concerne l'organisation de séminaires sur la planification halieutique et l'autre la nomination d'experts de la planification des pêches chargés de donner des avis, d'établir des unités de planification et de former du personnel de contrepartie.

La asignación de responsabilidades de la pesca debiera confiarse a un personal especialmente preparado y no a los planificadores económicos y agrícolas o incluso a especialistas en pesca con antecedentes técnicos, científicos o de administración general. Las características esenciales de los recursos pesqueros, como son la "invisibilidad," movilidad, carencia de derechos de propiedad y la producción pesquera, por ejemplo, la amplia gama de combinaciones de medios/producción, exigencias técnicas y de gestión, remuneración de pescadores y utilización del pescado, hacen de ellas un "arte," en cuanto a la preparación de un inventario y las proyecciones de la oferta y la demanda, que un planificador que no esté familiarizado con cuestiones de pesca no es de esperar conozca a conciencia. Los especialistas en pesca carecen de conocimientos para seleccionar los proyectos y sus actuaciones en la planificación, por regla general, no son mejores que las de los que no están especializados.

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Se resumen las técnicas fundamentales de la planificación por sectores y se describen los métodos de ajustarlas a los planes globales económicosociales. Se dan ejemplos relativos a los países que bordean el Atlántico centro-oriental enumerando diversos tipos de preguntas que podrián hacer los planificadores al comenzar o al evaluar los programas.

Se mencionan dos propuestas para mejorar la planificación del desarrollo pesquero; una para el estudio de la planificación de la pesca y la otra sobre el nombramiento de expertos en planificación pesquera para que asesoren, instituyan dependencias de planificación y capaciten al personal de contrapartida.

Fisheries Planning Requires Specialized Skills and Experience

FISHERIES development planning is still an undeveloped discipline in a large majority of countries. Developed countries usually consider the sector too small to warrant specialized attention and rely on agricultural planners to include fisheries in their proposals. In developing countries with a sizable fisheries potential lack of systematic fisheries planning often reflects the retarded development of the planning apparatus in general. In other cases the planners may lack acquaintance with the fisheries sector or, where fisheries staff have been given specific responsibilities for planning, they may not be familiar with the concepts and techniques of economic and social planning. Only in centrally planned countries, where mathematical techniques are used for allocating economic resources to all branches of the economy, has a more sophisticated approach to fisheries development planning been adopted.

Scarcity of private entrepreneurial initiative and the "atomistic" character of the industry compel most of the developing countries that seek to promote fisheries to resort to some form of planning. Experience has shown that the objective of rational fisheries planning will not be achieved if the responsibility for drawing up proposals is vested with overall economic planners or with staff specialized in agricultural planning. Fisheries resources and their exploitation and utilization have many distinctive features; an understanding of these is essential for plan formulation, and without some fisheries background a planner cannot be expected to know sufficiently well how to make intelligent decisions. While some fisheries operations, such as aquaculture, have much in common with agricultural operations, the exploitation of wild resources usually requires consideration of factors that have little or no relevance in agriculture:

NATURE OF THE RESOURCE

(a) Inventory-taking, which is essential for planning, presents special problems since the resource is "hidden" under water, and many stock assessment methods used for wildlife (such as aerial surveys) cannot be applied. The high degree of mobility of some stocks contributes to assessment difficulties.

(b) Projections of total availability are complicated not only by "invisibility" and "mobility" but also by differences in reaction of the large number of species to environmental factors, and to the intensity of the fishing effort.

(c) Estimates of availability to the individual user present further difficulties, because most wild stocks are "common property natural resources," whose exploitation is not legally restricted to one owner, and where no single user can control the take of others. This circumstance tends to attract so many producers and to lead to such a high pressure on the resources that unless timely action to limit entry into the fishery is taken, fishing becomes unprofitable. Eventually even the ability of the resource to renew itself is placed in jeopardy.

These factors make fishery resource management a special "art," requiring not only mastery in interpretation of statistical material but also a high degree of skill in filling gaps in scientific, technical, economic, and political knowledge relevant in trend projections.

FISH PRODUCTION

(a) Planning for physical inputs in fish production operations is very different from that in agriculture. Matching inputs of vessels, engines, gear, and auxiliary equipment to the availability of the stock to achieve a techno-economic optimum in exploitation is considerably more complicated than planning the use of farm machinery, seeds, and fertilizer for a given acreage of an agricultural crop.

(b) For large-scale fishing operations, technical skills and entrepreneurial independence in decision-making are essentially of a level not called for in agricultural operations.

(c) Another peculiarity of fisheries operations is the share-system of crew remuneration prevalent in many fisheries, which confers upon the fishermen the attributes of both labor and entrepreneurship and which consequently has an impact on productivity.

(d) The ease with which boats, gear, and equipment can be moved from place to place gives many fishermen in small-scale operations a degree of geographic mobility not possessed by farmers.

FISH UTILIZATION

Once the fish has been caught, the differences in pattern from agriculture are perhaps less striking, but are pronounced enough to affect the planning process. Utilization is influenced by physical characteristics of the fish (size, fat content, nutritive content, proportion of meat to bone, etc.), the "consumer image" of the species, relative changes in supply and demand trends, and innovations in handling, processing, and distribution. These factors often bring about radical shifts, even over the short run, in the demand for specific species and product forms. The alternatives of processing at sea or on shore affect not only the planning for land facilities but also the techno-economic character of the fish-producing unit. Transport and storage may require separate facilities because of the high degree of perishability and odor-producing characteristics of fish and fishery products. Odor also has a bearing on planning the location of processing facilities. With regard to demand, elasticity of substitution with meat (a factor on which only a few reliable empirical studies have been carried out to date) introduces a special element of uncertainty that greatly complicates planning. Other factors accounting for significant differences in the demand for fishery products are related to geographic region, nationality, religion, and development of the distribution system.

Assignment of the task of sectoral development planning to the fisheries specialist has usually been no more satisfactory than reliance on overall economic and agricultural sector planners. The majority of fishery administrators are trained in the physical sciences, technological disciplines, or general administrative work. They have had no opportunity to acquire specialized experience in planning techniques. They have a tendency to propose projects closely related to their fields of specialization without the necessary consideration of overall development objectives and prior determination of economic and social benefits, or, in the case of general administrators, compromise projects to meet specialist demands.

Other Requirements for Rational Fisheries Planning

Assignment of responsibilities to the wrong people does not by any means explain all failures in national fisheries planning. Apart from natural factors (such as the sudden disappearance of pelagic stocks from fishing grounds), debacles may be attributable to a planning apparatus too small for the tasks it is intended to accomplish, employment of unsuitable planning techniques, or unpredictable developments abroad. National planning has become more difficult in recent years because unilateral extension of fishery zones by a number of coastal countries has had serious effects on other countries that had had free access to the resources within the newly claimed zones. Recipient countries often consider foreign aid as a "gift horse" and disregard the unhappy consequences it may have on long-term development in the absence of rational plans for its application. Changes in foreign trade are often unpredictable, especially where they are directly related to international political developments and realignments of currency exchange rates. And havoc may be wrought even with the best-laid plans through uninformed domestic political interference and corruption in high places.

COORDINATION OF NATIONAL AND SECTORAL PLANNING

The possibility that outside forces may interfere with the formulation and implementation of fisheries plans does not absolve governments from responsibilities for making appropriate arrangements for planning. These will have to include specialized sectoral planners as well as improved communications between them and the planners responsible for other sectors, and for overall planning. National plans cannot be realistically formulated without a proper economic appraisal of sectoral proposals, and their contribution to national economic and social objectives cannot be properly ascertained except within the framework of the national plan. Good planning, therefore, requires a constant two-way flow of information between the planners at the higher (national) and at the lower (sectoral) levels, and willingness on the part of both to accept adjustments. This process is called "successive approximation" in planning terminology.

GUIDELINES FOR DEVELOPMENT PROJECTS

Fisheries planning aims at providing guidelines for the choice of development projects – where, when, how, and in what order to implement. What projects to propose hinges on overall objectives of economic and social policy. Economic plans that limit themselves to setting an output target (e.g. "a 20% increase in fish production is foreseen by the year...") are less useful than plans assigning specific tasks (e.g. "fisheries development is expected to play a major role in helping to improve living standards of the population settled along the . . . coast, which will have to continue to regard the sector as the single important source of gainful employment; it is to contribute. . . foreign exchange earnings through promotion of export-oriented fishing activities"). While still vague, phraseology of this sort contains sufficient clues for the fisheries planner to start drawing up a program. He knows that he must give first consideration to projects to boost earnings of the poorer fishermen in the region, and then to projects based on the exploitation of resources with a good export demand that can be carried out with a minimum expenditure of foreign exchange (e.g. development of shrimp resources of a quality accepted in the more attractive hard currency markets, and which can be caught and processed for export locally). If the two-way process of planning is to be fully effective, the planner would not necessarily have to stop at this point. If favorable development opportunities along other lines can be foreseen (e.g. offshore fishing with large vessels to catch cheap fish for domestic markets), additional proposals might be submitted, giving the overall planners an opportunity to change the order of priorities of the tasks assigned to the sector. If the increase in protein supplies for domestic nutrition rates is a top priority, proposals might have to include plans to secure inexpensive foreign supplies.

ASSESSMENT OF COMPARATIVE PROFITABILITY

An indication of priorities is merely the starting point for the planner's work. Where, for example, foreign exchange earnings are considered of importance, the planner will have to investigate first which projects are best suited to satisfy it. For these purposes he will have to make comparisons of the estimated profitability of various feasible projects (such as those based on shrimp versus tuna resources, projects located in one area versus in another, etc.). Furthermore, for every feasible project, there will be comparisons based on variations in scale of output and composition of inputs.

Making profitability comparisons involves an ability to predict the values of the variables (i.e. receipts for output and expenditures for input) affecting the measure of profitability as well as the choice of an appropriate measure of profitability. The values of the variables (i.e. the quantities and prices of inputs and outputs) are affected by three kinds of considerations: technical, human and managerial, and economic. The technical examination of a project proposal requires a determination of the internal consistency of the physical input and output estimates.

Similar probing is necessary for manpower and institutional requirements. The "economic" aspects of the profitability analysis are concerned with the assumptions lying behind the prices of inputs and outputs.

There is no need to discuss here the various measures of profitability that have been developed for the comparison of project receipts and expenditures, but it is necessary to stress that, in order to permit comparisons, a standard measure should be employed for projects initiated under similar conditions.

The planner proceeds with his profitability analysis like a private firm until he comes to the pricing of receipts and expenditures; then where "social" costs and benefits differ from "private" costs and benefits, he has to substitute "shadow prices." The ultimate responsibility for social cost–benefit analysis lies with the national planner who has to make the comparison between sectoral contributions.

PLANNING AS AN ART

As described above, the planning procedure appears more like a mathematical exercise than the art it really is. In many instances faulty planning is due not so much to mistakes in manipulating data as to inability to make a realistic appraisal of those aspects that are difficult to quantify (skills, abilities, and motivations of people connected with the industry, speed of technological and structural changes, etc.). Much of the "art" of planning has to do with the proper phasing of development activities (i.e. decisions on when and in what order to initiate projects or to schedule specific sub-projects) and raises such questions as: "Is the situation ripe for the proposed fisheries project?", "Have the consequences which the project is likely to have on other developments in and outside the sector been appropriately considered in phasing the proposal?", "Have opportunities for fisheries development arising through implementation of projects in other sectors been properly taken into account in scheduling sectoral development?" and "Are the sub-projects making up the proposal scheduled so as to diminish the likelihood of serious bottlenecks?".

Decisions on the timing and scale of projects must take account of the country's technical and financial ability to undertake certain tasks, as well as the economic and social climate in which they are to be implemented. Where a proposal relates to the exploitation of common property fishery resources, timing and scale will often be influenced by the plans of other countries. These may have a disincentive effect or, in some instances, where the belief prevails that the one who "gets in first" is likely to benefit most, may be a spur to expansion. Timing also depends on forecasts of likely technical and market developments at home and abroad, which may make it advisable to postpone or advance starting dates of projects.

IMPACTS ON OTHER DEVELOPMENTS

Projects that are fully justifiable from a sectoral standpoint and meet the profitability-comparison test may have to be rephased because of the impact they will have on development elsewhere. For example, a major fisheries expansion program may require a buildup in fishing boat construction over a limited period of time, which may not be reconcilable with sound long-term development of this industry.

Developments in other sectors of the economy may have a direct impact on fisheries planning. These include projects in the field of communications, which may provide access to new fishing areas or market centers; dams, reservoirs, man-made lakes, whcih may threaten existing fisheries or create opportunities for new fisheries; harbor and port installation projects, which add to landing and handling facilities; and industrialization and urbanization projects offering improved facilities for processing and distribution of fishery products. Also, fisheries will be affected by development of the commercial and educational infrastructure.

Increased awareness of the mutual relation between economic development and environmental conditions and the mounting intensity of competition for increasingly scarce resources have helped bring fisheries closer together with other sectors. The specialist is finding it more and more difficult, therefore, to deal with the complexities of fisheries planning.

COORDINATION AND TIMING

Finally, the phasing problem must be looked at from the standpoint of the smooth meshing of the sub-projects of a development proposal. There are many instances where technical mistakes in calculating input /output have led to delays and serious underutilization of capacity at various points of project execution, thus causing essentially sound projects to become unprofitable. There are also many instances where unrealistic manpower planning is responsible for nonfulfilment of expectations. In particular, overoptimistic assumptions about the quality of management and the skill of the labor force often lead to underestimation of the time needed to bring a project to full operation.

Delays are not always attributable to bad planning. In some instances they are the consequence of the adoption of a deliberate strategy of development that, through "shock treatment" (such as by planning a big push in one sphere), hopes to bring the development process to a threshold where growth in other spheres will be generated. This strategy can be juxtaposed to a balanced growth strategy, which envisages concurrent expansion in all spheres.

The "big push" is often justified on the basis of urgency. For example, in one instance this strategy was defended on the basis of a military necessity to provide incentives for fishermen in a strategically important coastal area to stay there rather than emigrate to pursue more attractive livelihoods. As a rule, a "big push" can be accomplished only by allocation of an input quantity far in excess of what would seem reasonable. It cannot be sufficiently emphasized that such excessive costs should be carefully weighed against the benefits anticipated. Unfortunately it is not always possible to make a comparison on a strict accounting basis, since the values that reflect policy objectives (military security, prestige gain, etc.) in these instances may not be translatable into monetary terms.

Fisheries Development Problems in the Countries Bordering the Eastern Central Atlantic

West African experience includes an abundance of examples of the difficult choices faced in fisheries planning. The brief descriptions of a few cases, abstracted to some extent from reality but retaining characteristic features of common trends, may be sufficient to illustrate the need for expert skills in organizing and scheduling development activities. At the end of each "case," questions have been added to indicate points that economic and social planners would be inclined to raise on initiating or evaluating the activities summarized.

Case No. 1

The coastline of Country A, a large desert region sparsely settled by a nomadic population, is close to fishing areas rich in resources exploited by the fleets of overseas countries. The country has nothing to contribute in the way of material or human input or potential market outlets toward stimulating an economically viable fishery industry, and nearby fishery centers in other countries have been traditionally used as bases by the overseas fleets. Strategic and commercial reasons not related to fisheries induced overseas interests to invest in a sizable fishery complex in a port on the coast. After several years, despite serious efforts to promote increased supplies, utilization of the shore capacity is still less than 25%. The government is reported to have incurred substantial expenditure for infrastructure and provision of assistance to fishery companies to defray their operating costs.

Questions — What benefits could the country have derived if the foreign aid and investments that went into building up the fishery complex had been directed toward meeting other national objectives? Are the strategic and commercial advantages realized by the overseas interests adequate compensation for the losses on the fishery complex?

Case No. 2

Country B has a population with a fish-eating tradition, requiring imports to supplement domestic production. A large government expansion program including investment in a fleet of long-range fishing vessels and the organization of a fish distribution network (including modern fish terminals) was embarked upon, partly to replace imports and to increase local supplies, and partly for prestige reasons. Substantial foreign exchange expenditure commitments were involved; and high operational losses were incurred for a number of years because of delivery of unsuitable equipment, lack of domestic managerial know-how and technical skills, opposition by the traditional "mammy" retailers to the use of the modern terminal facilities, and a government price-fixing scheme that contributed nothing toward market expansion and merely benefitted certain individuals.

For years state initiative and support for the long-range fleet had a depressing impact on the growth of an apparently healthy commercial coastal fishery created by a handful of imaginative private entrepreneurs. These were discriminated against through withholding of foreign exchange allocations and licenses for the import of essential inputs. Another adverse effect was the lack of support for the large number of labor-intensive canoe fishery operations along the coast conducted by fishermen belonging to tribes with an age-old fishery tradition. Support that was given to small-scale operators was limited to the solution of specific technical or institutional problems.

Questions — Were the potential gains in prestige and in accomplishment of nutritional objectives through the creation of a sizable long-range fishing fleet worth the risks involved in the ambitious phasing of the program? (In view of the heavy demand on foreign exchange that its implementation involved, the import substitution argument should have been suspect from the very start.) Would a balanced allocation of development support among the three sectors — canoe fisheries, large-scale, and small-scale commercial operations — have met economic and social objectives of development better than the one-sided emphasis on long-range fisheries? Could the support to small-scale operations have been used more effectively by establishing fewer but fully integrated projects?

Case No. 3

Country C has a huge population and large requirements for fish protein, which it has not been able to meet fully through the exploitation of coastal and inland waters. Rather than develop a long-range fleet of its own, it has relied on supplies of inexpensive frozen fish landed by foreign fleets and by vessels chartered to domestic companies, giving increasing emphasis to the latter because of foreign exchange stringency. But since charter arrangements constitute a drain on foreign exchange, the feasibility of organizing national long-range operations is under investigation. In the meantime, expanding charter operations indirectly help to create a long-range fleet through the building of an infrastructure. Improvements are essential in transportation, storage, and marketing facilities to rectify the uneven distribution pattern.

Questions — Given the priorities accorded to consumption and to saving foreign exchange, what would be an optimum allocation of expenditures between imports, charter operations, and domestic fleet development? What are the implications on the planning of fish distribution facilities and capacity of large fluctuations in import and charter supplies caused by changes in foreign exchange availability?

Case No. 4

Country D had made rapid progress in marine fisheries development, but this has not always been reflected in increased earnings. In the recent past the industry "has in different sectors suffered both from over- and under-capacity." The export-oriented shrimp industry, which grew rapidly up to 1969, has suffered from a marked fall in the catch per unit of effort. Poor maintenance has handicapped the operations of handline vessels. Development of shore-based infrastructure and of the principal fishing port has not always kept up with expansion in fishing, and bottlenecks have become of increasing concern.

Questions — What criteria should be applied in planning major shore-infrastructure facilities where prediction of capacity utilization is complicated by the probability of drastic shifts in fisheries policy and wide fluctuations in abundance of the resources exploited? Has the input-use planning been done with proper evaluation of the effects of fishery regulation (by type), or its lack, on the distribution of welfare between different generations?

CASE NO. 5

In Country E construction of a commercial port, the siting of which had been decided on political grounds, has adversely affected the biological equilibrium in lagoon fisheries and thus the livelihood of a large segment of the population. Financing for the costly works necessary to restore the productivity of the lagoons could not be obtained, and efforts were directed instead toward transferring some of the lagoon fishermen to other marine fishing operations. Results were not always satisfactory because of the fishermen's lack of adaptability to new conditions, their unfamiliarity with cooperative enterprise (which the government tried to promote), and inadequacies of some of the local administrators responsible for the project. To meet growing supply needs in a region heavily dependent on fish protein, large imports of frozen fish by foreign long-range vessels had to be permitted. Since the coastal waters are too poor to provide a significant increase in catch, and since neither the rehabilitation of the lagoon fishery nor the establishment of a national long-range fleet appears to be economically feasible, a continuing large foreign exchange expenditure seems inevitable.

Questions — Could higher capital expenditures, inconvenience, and higher operating costs, which would have resulted from the choice of an alternative site for the commercial port, have been justified in terms of savings in social costs (as a result of preservation of the status quo in lagoon fisheries) and in economic costs (through avoiddance of foreign exchange expenditures to meet consumption requirements)?

CASE NO. 6

Research has been carried out for years on the distribution and abundance of certain pelagic species of potentially substantial commercial importance along a long stretch of West African coast. The objective is to make an assessment of resources for formulating management policies.

Question — At what point are benefits from marginal expenditures on research cancelled out by the social cost of postponed exploitation; in other words, how much research before development?

CASE NO. 7

The waters off West Africa are being fished by long-range fleets of a number of overseas countries and the pressure on resources in some areas is known to be heavy. Coastal countries that seek to develop their fisheries feel they have a priority claim to resources off their shores, and want to assume an increasing role in their protection and exploitation. Lack of political and economic bargaining power and lack of capital and know-how are considered major handicaps to the achievement of their objectives.

Questions — Will the cost of enforcement of claims to national jurisdiction be compensated by increased catches as a result of stock recovery? Are national objectives with respect to resource protection and exploitation more easily or appropriately attained by entering bilateral joint ventures or by "going it alone," with the expectation that foreign aid will supplement domestic effort? What are the possibilities of forming multinational joint ventures for the protection and exploitation of regional resources, which might permit reconciliation of the interests of all parties involved?

Conclusion

A good many more cases could be presented and a much larger number of questions raised on appropriate strategies for national and regional fisheries development. However, the examples cited are sufficient to show the range and complexity of problems confronted in deciding on courses of action and in scheduling activities.

While the need for training staff in fisheries planning operations is generally recognized, the question of the best way to accomplish this has never been fully discussed. FAO's efforts to sharpen priorities in formulating its program of work have led to increased emphasis on assistance in national development planning, and have prompted the FAO Department of Fisheries to draw up proposals for training specialists in planning. With the support of regional development banks and bilateral agencies such as the International Development Council of Canada, it is hoped that the Department will be able to organize national and regional workshops on fisheries planning, which will provide participants with an opportunity to work on the solution of specific planning problems relating to fisheries developments in their countries. It is further intended to draw the attention of FAO member countries and of agencies financing development assistance to the benefits that might be obtained from the appointment of fisheries planning experts to advise governments on plans, to organize sectoral planning units, and to train counterparts to staff these units.

La développement des pêches régionales en Afrique occidentale[1]

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Les zones de pêche au large des côtes de l'Afrique occidentale sont parmi les plus productives du monde. Les prises en 1970 y ont dépassé 2 millions de tonnes, soit environ deux fois plus qu'en 1960. Seul un tiers de ces prises est imputable aux canots et flottilles opérant en bordure de la région, le reste étant capturé par les gros navires toujours plus nombreux provenant de pays non africains.

La pêche constitue toujours une activité de subsistance dans tous les districts côtiers et rares sont les navires modernes basés sur place. Bien que des industries de transformation du poisson aient été créées dans plusieurs pays, elles ne produisent encore que faiblement, faute d'un approvisionnement suffisant en matière première.

La consommation de poisson — de mer et d'eau douce — dans la région serait d'environ 1 million de tonnes pour une population de 150 millions d'habitants, y compris les pays intérieurs du Golfe de Guinée. Bien que les importations fournissent 20% du poisson consommé dans la région, il y a un déficit d'un demi-million de tonnes. Sous la pression combinée de la croissance démographique et de l'augmentation des revenus, il se pourrait bien que ce déficit atteigne 1 million de tonnes au cours des dix années à venir.

La distribution inégale des zones de production ainsi que la demande générale de poisson ouvrent des perspectives à une expansion sensible du marché intra-régional. Il est évident que les états côtiers ont besoin de développer leurs pêches et leurs industries halieutiques.

Devant l'augmentation rapide des prises par des flottilles étrangères, un certain nombre de pays ouest-africains sont amenés à étendre leurs eaux territoriales au-delà de la limite des 12 milles, ce qui, à sont tour, incite les entreprises extérieures à coopérer avec les pays côtiers. La nouvelle stratégie devrait intensifier la participation de ces pays à l'exploitation de leur plateau continental.

Etant donné le faible degré de développement de région, une politique intégrée d'expansion s'impose. Celle-ci engloberait les petits et grands navires, la transformation et la commercialisation du poisson, l'évaluation et le contrôle des ressources, l'aquiculture et la formation à tous les niveaux dans le domaine des pêches. Les grandes lignes de cette stratégie sont exposées dans le document.

The fishing grounds off the coast of West Africa are among the most productive in the world. Catches in the area in 1970 were in excess of 2 million tons, an increase of about 100% over 1960s catch. Of this only a third was caught by canoes and fleets bordering the region, the rest by an increasing number of large vessels from countries outside Africa.

Fishing is still a subsistence activity in all coastal districts and locally based modern vessels are few. Although fish processing industries have been developed in several countries of the region they often remain at a low level of production because of insufficient supply of raw material.

Fish consumption in the area — marine and fresh water fish — is estimated at about 1 million tons for a population of 150 million, including the landlocked countries of the Gulf of Guinea. Although imports supply 20% of the fish consumed in the area, there is a deficit of half a million tons. This deficit could well reach

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[1] Préparé en vue de la "Conférence d'experts sur l'aménagement et le développement des pêches," de l'Organisation des nations unies pour l'alimentation et l'agriculture, tenue à Vancouver, C.-B., Canada, 13-23 février 1973.

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1 million tons in the course of the next decade under the combined pressure of population growth and rising incomes.

The uneven distribution of the producing areas and the general demand for fish suggests a potential for a large expansion of interregional trade. The need for the coastal states to develop their fisheries and fishery industries is obvious.

The rapid increase of the catch by foreign fleets is causing a number of West African countries to extend their territorial waters beyond the 12-mile limit. This, in turn, is inducing foreign concerns to seek cooperation with the coastal countries. A greater participation of these countries in the exploitation of the resources of their continental shelf should result from the new strategy.

In view of the low stage of development in the area an integrated policy for development is needed. This would cover small craft and large vessels, fish processing and marketing, resources assessment and monitoring, aquaculture and training, at all levels in fisheries. Such a strategy is outlined in the paper.

Los caladeros situados frente a las costas del Africa Occidental son de los más productivos del mundo. En 1970 se capturaron en esa zona más de 2 milliones de toneladas de pescado, con un aumento de cerca del 100% respecto a 1960. De este total, sólo un tercio fue capturado por canoas y flotas de países de la región; el resto lo pescaron grandes embarcaciones de países no africanos, cuyo número va en continuo aumento.

La pesca sigue siendo una actividad de subsistencia en todos los distritos costeros y las embarcaciones modernas con base en puertos locales on escasas. Aunque en varios países de la región han surgido industrias de elaboración de pescado, a menudo su producción es muy baja debido a la insuficiencia del abastecimiento de materias primas.

El consumo de pescado de la región — pescado de aguas marinas y dulces — se calcula en cerca de 1 millón de toneladas, para una pollación de 150 millones de habitantes, incluidos los países sin salida al mar del Golfo de Guinea. Aunque se importa cerca de un 20% del pescado consumido en la zona, hay un déficit de medio millón de toneladas, que podría llegar a 1 millón durante el próximo decenio a causa del aumento de la población y los ingresos.

Dado la desigual distribución de las zonas de producción y el generalizarse de la demanda de pescado, las posibilidades de expansión del comercio inter-regional son grandes. Es obvio, pues, que los estados costeros necesitan desarrollar sus pesquerías y sus industrias pesqueras.

El rápido aumento de las capturas de las flotas extranjeras mueve a muchos países del Africa Occidental a ampliar sus aguas territoriales por encima del límite de 12 millas, lo que, a su vez, induce a las empresas extranjeras a buscar la colaboración con los estados costeros. Esta nueva situación dará lugar, probablemente, a una mayor participación de estos países en la explotación de los recursos de su plataforma continental.

Dado el bajo estado de desarrollo de la zona, es necesaria una política integrada de desarrollo, que incluya construcción de pequeñas embarcaciones y grandes barcos, elaboración y mercadeo de pescado, evaluación y vigilancia de los recursos, acuicultura y capacitación a todos los niveles. De esto se ocupa el presente documento.

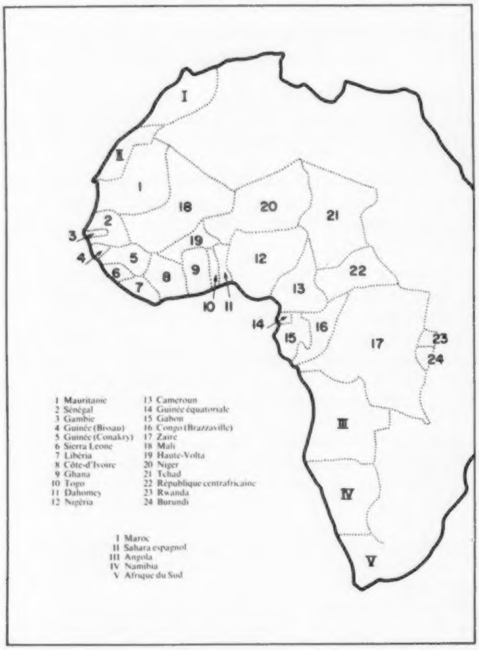
LES pêches de l'Afrique occidentale ont pris un essor rapide au cours des dernières années. Il y a seulement 10 ans, les activités halieutiques se limitaient pratiquement à la pêche artisanale effectuée essentiellement à l'aide de pirogues, mais des dernières années de gros bateaux de pêche en provenance de l'étranger et de certains pays africains ont commencé à opérer dans cette région.

Pêches Artisanales

Du Cap Blanc à l'embouchure du Congo, on compte environ 80,000 pirogues manoeuvrées par des pêcheurs dont le nombre est à peu près le triple de ce chiffre. En 1969, on évaluait les prises de cette flottille à 360,000 tonnes, dont 50,000 tonnes (17%) pêchées dans les lagunes et autres eaux stagnantes du Dahomey, du Nigeria et de la Côte-d'Ivoire. Quatre-vingt-quinze pour cent des prises totales proviennent des pays situés entre le Sénégal et le Cameroun. Le Sénégal vient en tête avec 35% des prises (125,000 tonnes), tandis que le Nigeria et le Ghana ont chacun à leur actif environ 20% des captures (respectivement 73,000 et 60,000 tonnes).

Compte tenu de l'évolution démographique, on suppose qu'au cours des dix dernières années, les captures ont augmenté de 30 à 40%. Un volume moyen de 25 tonnes et de 12 tonnes de poisson par pirogue a été enregistré respectivement au Sénégal et au Ghana. Au Nigeria, on estime que les prises moyennes par pêcheur varient de 0,6 tonne (pêches lagunaires) à 1,5 tonne (pêches maritimes); le revenu annuel moyen par pêcheur s'échelonne de 100 dollars E.-U. (pêches lagunaires) à 150–400 dollars E.-U. (pêches maritimes). Des enquêtes effectuées au Dahomey il ressort que le nombre moyen de sorties par pirogue est d'environ 50 par an. Les pirogues de mer mesurent de 8 à 12 m de long et celles des lagunes de 5 à 8 m; il s'agit, dans presque tous les cas, d'embarcations creusées dans des troncs d'arbres.

Les Sénégalais et les Ghanéens, qui semblent être les pêcheurs les plus habiles de l'Afrique occidentale, ont introduit leurs techniques de pêche dans plusieurs pays. Les engins de pêche comprennent des filets pouvant atteindre de 150 à 2500 m de long (filets à sardinelles, filets à bonga, arts traînants et sennes de plage) utilisés par des groupes de 15 à 30 pêcheurs; des filets fixes, filets à requin et filets dérivants pouvant atteindre jusqu'à



3000 m de long; des éperviers et filets à crevettes, des lignes et hameçons et des pièges de différents types et formes. L'engin le plus communément employé est le filet maillant.

MÉCHANISATION

Au cours des 20 dernières années, la mécanisation a fait d'importants progrès au Sénégal et au Ghana, où environ 50% des pirogues sont motorisées. Cela est dû essentiellement à l'action dynamique des services des pêches de ces pays. L'apparition de la pêche mécanisée au Ghana a été liée à la mise en oeuvre d'un programme de formation à l'intention des pêcheurs désireux d'acquérir des embarcations à moteurs. Des facilités de crédit ont été mises à leur disposition à cet effet dans les pays susmentionnés.

Au Dahomey et au Togo, 20% des pirogues de pêche sont motorisées. Le programme de mécanisation a débuté en 1964 dans le cadre d'un projet CMCF prérogant la livraison de 80 moteurs hors-bord. Deux cents pêcheurs ont tout d'abord été initiés au fonctionnement des moteurs, puis trois centres pilotes ont été mis sur pied. Le Service des pêches a créé un fonds de roulement et organisé un service technique pour la réparation et l'entretien des moteurs.

D'après les chiffres fournis par le Centre pilote de Ouidah, la motorisation permettrait de tripler les captures. Toutefois, en raison des coûts de fonctionnement plus élevés, elle suppose l'emploi de techniques et d'engins de pêche plus modernes, ainsi que la création de services d'entretien et de réparation et l'octroi de possibilités de crédit.

En se fondant sur les résultats obtenus au Dahomey et au Togo, la Coopérative for American Relief Everywhere (CARE) a lancé au programme analogue en 1967 à l'intention des pêcheurs de la côte orientale du Nigéria. L'objectif visé était l'organisation de coopératives de pêcheurs et la location-vente de moteurs hors-bord. Dans les autres pays de la région, moins de 4% des pirogues sont motorisées, le taux moyen de mécanisation étant d'environ 9%. En 1963, le Gouvernement du Dahomey a passé un contrat prévoyant la vulgarisation des techniques de pêche à la ligne à main par 20 pêcheurs sénégalais qualifiés. Au Sénégal, des expériences plus récentes ont eu pour objet d'encourager l'emploi de sennes coulissantes, de filets maillants encerclants, de trémails, et de méthodes de pêche au feu dans la pêche en pirogue. Des prises allant de 1,5 à 4 tonnes par pose de filets ont été réalisées avec des sennes coulissantes au large de Dakar, M'Bour et Joal, alors que les captures ont atteint 200 kg seulement avec les filets maillants traditionnels. Des essais effectués avec des trémails et des filets-pièges ont démontré qu'il était possible de prolonger la saison de pêche dans la région de Saint-Louis. Depuis 1967, le Ghana s'efforce de mettre au point de nouvelles techniques — telles que pièges pour la pêche à la langouste, appâts artificiels pour la pêche du thon à la ligne et petits chaluts. Les filets maillants encerclants traditionnels sont transformés en sennes coulissantes. Des démonstrations ont également été faites en Côte-d'Ivoire afin de faire adopter dans la pêche artisanale des filets plus modernes, des treuils en bois, des catamarans, des petits moteurs Diesel intérieurs, ainsi que du matériel portatif pour la pêche au feu.

Un projet visant la mise en valeur des pêches au moyen de démonstrations et de stages de formation est actuellement en cours d'exécution sur les lacs Leopold II et Tumba (Zaïre) au titre de l'aide bilatérale; un chaland à moteur est utilisé pour cette réalisation.

CONSTRUCTION DE BATEAUX

Des bateaux de pêche mesurant de 7 à 24 m de long ont été construits au Sénégal, en Guinée, en Côte-d'Ivoire, au Ghana, au Dahomey et au Nigéria. Entre 1962 et 1966, environ 40 constructeurs de bateaux ont été formés au Sénégal par des experts FAO, et on a mis au point plusieurs types d'embarcations de pêche de 13 à 16 m de long afin d'assurer la transition entre les pirogues traditionnelles et les bateaux de pêche plus modernes. A la suite de ces mesures, on a créé deux coopératives de construction navale qui ont fabriqué 30 bateaux (13 m par 70 CV) pour la pêche à la ligne. Au début ceux-ci ont donné des résultats satisfaisants. Cependant, en raison d'un mauvais entretien et de l'insuffisance des crédits accordés aux pêcheurs, les chantiers navals ont cessé leurs activités en 1967. Le Gouvernement se propose actuellement de reprendre ce projet et une aide financière a été demandée à la Banque internationale pour la reconstruction et le développement en vue de la construction de nouvelles unités. En Côte-d'Ivoire, des chantiers privés construisent des senneurs en bois d'une dimension variant entre 20 et 24 m. Les chantiers navals de la Ghana Industrial Holding Corporation (GIHOC), à Tema et Takoradi, ont mis au point et construit des senneurs ainsi que des chalutiers-senneurs dont les dimensions varient entre 12 et 14, voir 18 m. Les bateaux de construction locale mesurant entre 8 et 15 m de long constituent actuellement une importante flottille de plus de 200 unités. Celle-ci assure une part importante des prises ghanéennes de sardinelles et constitue une étape décisive sur la voie qui mène à l'industrialisation de la pêche artisanale.

Cette modernisation est une tâche de longue haleine et la pêche côtière continuera de jouer pendant longtemps encore un rôle important dans les pays d'Afrique occidentale, tandis que la mécanisation des pirogues traditionnelles et la construction de bateaux modernes continuera de prendre de l'ampleur. Les efforts visant à accélérer le développement des pêches traditionnelles exigeront la création d'un nombre accru de services de vulgarisation, de coopératives, de facilités de crédit et d'installations de débarquement, ainsi que la mise en oeuvre de projets pilotes de démonstration. Au Ghana et au Sénégal, on a motorisé jusqu'à 50% des pirogues, alors que la moyenne est de 9% pour l'ensemble des pays africains. Dans les conditions actuelles, il serait impossible d'accélérer le rythme de la motorisation dans les autres pays, à moins de faire un effort spécial pour venir en aide aux pêcheurs. Compte tenu de l'expérience acquise, le mieux serait d'accorder des prêts à ces derniers, de créer des fonds de roulement, d'exempter l'essence et les moteurs des taxes d'importation et de créer des ateliers et des services d'entretien et de réparations. Il serait en outre nécessaire de mener campagne intensive pour initier les pêcheurs au fonctionnement des moteurs.

On devrait encourager la construction de bateaux de 11 à 18 m de long, de conception intermédiaire entre la pirogue traditionnelle et les embarcations modernes, comme l'on fait le Ghana et le Sénégal. Le Nigéria a également formulé une demande de projet visant la création d'un chantier naval sur le lac Tchad, la mise au point d'un type d'embarcation adapté aux conditions locales, la formation de constructeurs de bateaux et l'exécution d'un programme de construction. Ce projet pourrait servir de modèle à des initiatives du même ordre dans les eaux intérieures et les zones maritimes de l'Afrique.

Les projets déjà réalisés ou en cours nous enseignent que l'acquisition des techniques de construction navale est un processus long dont l'efficacité dépend d'une formation intensive, de l'octroi de crédits aux pêcheurs, d'une aide et d'un contrôle techniques constants et d'un appui financier suffisant. En raison des changements dûs à la mise en service de bateaux nouveaux, ainsi que d'engins et de techniques de pêche plus efficaces, et de l'augmentation des coûts de fonctionnement, il convient d'effectuer des études avant d'entreprendre un programme de fonctionnement, il convient d'effectuer des études avant d'entreprendre un programme de construction navale sur une vaste échelle. Pour compenser les coûts élevés de la construction navale et assurer une meilleure coordination lors de la programmation et de la conception des bateaux, la gestion des chantiers devrait se faire à l'échelle régionale ou en coopération entre les pays.

CRÉDITS

L'octroi de crédits est indispensable au développement de la pêche artisanale. La principale difficulté consiste à mettre au point en système pratique pour le remboursement des prêts. Les mesures ci-après ont été récemment recommandées au Sénégal, compte tenu de l'expérience acquise ce domaine:

Création d'un Conseil de gestion composé de pêcheurs, de fonctionnaires des pêches et de représentants des banques. Le Conseil serait chargé de superviser l'octroi des prêts et les activités des bateaux de pêche. Il veillerait à ce que les prêts soient remboursés grâce à l'exploitation commerciale des bateaux et s'assurerait que leur réparation et leur entretien sont effectués de façon satisfaisante.

Le Conseil fixerait la politique à suivre en matière d'octroi des prêts — notamment durée, taux d'intérêt et garanties requises — en veillant plus particulièrement à ce que le pêcheur ne devienne pas propriétaire de son bateau avant un an ou tant que la preuve n'a pas été faite que le bateau sera exploité et entretenu convenablement.

Cette formule de crédit pourrait s'appliquer aux autres pays de la région. Une récente étude effectuée sur le même sujet par un expert conseil de la FAO dans la région du sud-est asiatique souligne qu'un système efficace de crédit doit être soutenu par un apport massif de facteurs de production et par des institutions appropriées.

COOPÉRATIVES

Il existe, dans plusieurs pays d'Afrique occidentale, des coopératives de pêcheurs de dimensions modestes, il est vrai. Jusqu'à présent leurs résultats ont été décevants en raison du manque d'esprit coopératif de leurs membres, ce qui reflète peut-être leur très faible niveau d'instruction. Pour améliorer ce niveau, il faudrait assurer une formation régulière au niveau des villages. Ces coopératives pâtissent également d'une gestion médiocre qui ne permet pas aux pêcheurs de profiter des occasions offertes ou de se perfectionner dans leur travail. Ces difficultés ne peuvent être surmontées sans l'appui continu et énergique du gouvernement.

CONCLUSIONS

Le développement des pêches artisanales dépend essentiellement d'un resserrement des liens entre les services gouvernementaux et les communautés de pêcheurs, ainsi que du développement de la formation professionnelle. Ainsi qu'il a été souligné à la Conférence de la FAO réunie à Kampala (novembre 1968), les pays en voie de développement ne pourront accroître la productivité par unité de superficie et par habitant qu'en modernisant les techniques et les méthodes de production et en créant des services de vulgarisation et une infrastructure appropriée pour former les pêcheurs à ces techniques. Mais avant de créer ou d'élargir de tels services, il faut entreprendre des études approfondies sur la façon dont les dépenses courantes peuvent être progressivement réduites jusqu'à ce que les collectivités locales puissent en assumer la charge.

Jusqu'à présent, la procédure normale suivie pour former des vulgarisateurs consistait à les choisir parmi les étudiants ayant atteint un certain niveau d'instruction, sans avoir une grande expérience pratique des pêches. Mais l'adoption de méthodes, d'engins et de bateaux de pêche modernes nécessite le recours à des techniciens qualifiés ayant une solide formation halieutique, même si la culture générale leur fait défaut. Il faudrait donc choisir les vulgarisateurs parmi ces deux catégories et les intégrer dans des équipes d'action sur le terrain.

En résumé, le développement des pêches artisanales devrait suivre le schéma suivant:

(a) Des enquêtes sur les types actuels de bateaux, d'engins de pêche, de services de commercialisation et autres facilités devraient être effectuées par des techniciens ayant une expérience pratique des pêcheries de pays confrontés aux mêmes problèmes.

(b) A la suite de ces enquêtes, il conviendrait de formuler des recommandations visant à mettre en oeuvre des projets pilotes portant sur un nombre limité de bateaux et d'engins de pêche, afin de mettre en lumière les aspects économiques de l'adoption de procédés, de bateaux et d'engins de pêche nouveaux. Les projets pilotes permettraient de déterminer si les nouvelles méthodes constituent un véritable facteur de progrès. Ils devront être exécutés par une équipe d'experts qualifiés, bénéficiant eventuellement d'une aide extérieure, et aboutir à des programmes de démonstration.

(c) Après avoir bénéficié de ces démonstrations et d'une formation satisfaisante, les pêcheurs recevraient des prêts dans le cadre d'un système de remboursement.

Pêches industrielles et semi-industrielles

BATEAUX DE PÊCHE

Les bateaux de pêche opérant au large des côtes de l'Afrique occidentale peuvent être classés approximativement en quatre catégories:

(a) *Chalutiers hauturiers* venant des pays orientaux, extrême-orientaux et occidentaux pour pêcher principalement le maquereau, le chinchard, la sardinelle et les poissons démersaux. Ces bateaux opèrent essentiellement entre 10° et 22° de latitude Nord et, en 1968/69, on en comptait plus de 600. On estimait que leurs prises excédaient au total 700,000 tonnes. En 1970, on a également signalé dans la même région un certain nombre de navires-usines et plus de 100 bateaux à senne coulissante. Une flottille étrangère de chalutiers-crevettiers et de langoustiers opère également principalement au large du Sénégal et de la Mauritanie.

(b) *La flottille canarienne* composée d'environ 440 unités qui opèrent surtout au large du Rio de Oro. Environ 130 petits senneurs appartenant à cette flotte et dénommés "tarafiers" avaient coutume d'opérer à partir de Nouadhibou pendant la saison dite "maigre." Jusqu'en 1966, les prises effectuées dans les eaux mauritaniennes par 220 "tarafiers" s'élevaient environ à 50,000 tonnes de poisson, vendu pour un tiers aux pêcheries de Nouadhibou et pour le reste aux Canaries. Le commerce avec les Canaries a fortement décliné au cours des dernières années et l'essentiel des prises est maintenant débarqué à Nouadhibou.

(c) *Une flottille d'environ 300 palangriers et senneurs* venant essentiellement du Japon, de la Corée, de Taïwan, de la France et des Etats-Unis; ces bateaux accostent dans les ports de Pointe-Noire, Tema, Abidjan, Freetown, Dakar et Las Palmas pour le transbordement des prises. Environ 100,000 tonnes de thons ont été ainsi transbordés en 1969 et l'on en a débarqué 10,000 tonnes à Dakar et Abidjan aux fins de transformation industrielle.

(d) *Une flottille d'environ 600 unités de 13 à 80 m de long opérant à partir de différents ports de l'Afrique occidentale.* En 1969, ces bateaux, manoeuvrés par environ 9000 pêcheurs africains et 900 expatriés, ont débarqué 900,000 tonnes de poissons, 55,000 au Ghana (27%), 50,000 en Côte-d'Ivoire (25%), 30,000 au Sénégal, de 14,000 à 16,000 au Congo Kinshasa et au Cameroun (7%), 12,000 (6%) au Congo Brazzaville et 8,000 (4%) au Nigéria; des prises ne dépassant pas 1000 à 4000 tonnes ont été enregistrées dans les autres pays d'Afrique occidentale. Il est difficile d'établir une classification pour cette flottille en raison du manque de précision des données dont on dispose. D'après une enquête effectuée en mars 1971, les estimations provisoires ci-après ont été avancées: Chalutiers: 320, y compris 140 crevettiers; Senneurs: 200, essentiellement concentrés au Ghana (70%) et en Côte-d'Ivoire (20%); Bateaux d'environ 13 m de long équipés de lignes à main: 18 (90%) au Sénégal; Bateaux-congélateurs de haute mer: 44, dont 26 chalutiers au Ghana, 20 thoniers au Sénégal et en Côte-d'Ivoire et 4 chalutiers-congélateurs au Cameroun.

Ces bateaux présentent les caractéristiques suivantes: 245 d'entre eux (43%) mesurent de 13 à 20 m de long pour une puissance de 60 à 200 CV, 277 (45%) mesurent de 20 à 30 m pour une puissance de 200 à 500 CV et 60 (11%) mesurent de 30 à 80 m pour une puissance de 500 à 2000 CV.

Les engins de pêche comprennent: des sennes coulissantes de 500 à 1000 m de long, de 50 à 100 m de haut et dont le maillage (mailles étirées) varie de 80 à 100 mm; des chaluts dont la corde de dos mesure de 20 à 30 m et dont le cul de chalut est formé de mailles étirées de 18 à 30 mm. Les filets maillants encerclants utilisés par les pêcheurs ghanéens "alinets" et ceux utilisés par les "tarafiers" canariens de Mauritanie ont pour dimensions 300 x 30 m. Leur maillage (mailles étirées) est d'environ 50 mm. Les chaluts de fond à grande ouverture utilisés par les projets FAO dans la région se sont révélés des engins efficaces pour pêcher les poissons démersaux et semi-pélagiques.

Il existe dans presque tous les ports de pêche de l'Afrique occidentale des entrepôts frigorifiques, ainsi que des installations de congélation et de fabrication de la glace, mais il semble que les pays n'ayant pas accès à la mer en soient dépourvus. La chaîne du froid dans 17 pays a au total une capacité de 55,000 tonnes — 23% au Ghana et environ 12% respectivement au Nigéria, au Sénégal, en Mauritanie et en Côte-d'Ivoire. Les usines de congélation et de réfrigération peuvent atteindre respectivement une capacité de 1100 et 1500 tonnes par jour.

INDUSTRIE DE TRANSFORMATION

L'industrie de transformation du poisson, y compris les conserveries, est concentrée à Nouadhibou (Mauritanie), Dakar, Abidjan et Accra. Ces installations représentent environ 65% des investissements totaux de l'industrie de transformation du poisson en Afrique occidentale. Il semble que Nouadhibou dispose de l'installation la plus importante, avec une capacité annuelle lui permettant de produire 40,000 tonnes de farine de poisson, 15,000 tonnes de poisson salé-séché et 1500 tonnes de conserves. La capacité totale de transformation a été évaluée à environ 300,000 tonnes de matière première par an. Les investissements dans les usines de transformation du poisson dépassent 15 millions de dollars E.-U.

Les fabriques de conserves de Dakar et d'Abidjan, dont la capacité atteint 20,000 tonnes par an, traitent l'albacore, la bonite à ventre rayé et d'autres espèces de thonidés. En 1970, ces usines ont exporté environ 18,000 tonnes de thon en boîte. Les conserves de crevettes prennent actuellement de l'expansion dans ces ceux villes, ainsi qu'au Nigéria, au Cameroun et au Libéria. Les exportations de poisson congelé à partir de Nouadhibou ont atteint environ 10,000 tonnes en 1970. Des conserveries de clupéidés (sardinelle et bonga) ont commencé à fonctionner sur une petite échelle au Sénégal et en Côte-d'Ivoire. En 1970, 70,000 tonnes de poisson ont été livrées aux usines de la Mauritanie, du Sénégal et de la Côte-d'Ivoire en vue de leur transformation industrielle. Les investissements totaux effectués dans l'industrie de traitement du poisson atteignent approximativement 40 millions de dollars E.-U. dans la région du Golfe de Guinée.

Des projections fondées sur le taux de croissance démographique en Afrique occidentale indiquent qu'il faudra, en 1975 et en 1980, 500,000 et 800,000 tonnes supplémentaires de poisson. Au Nigéria, ainsi que dans cinq autres pays, où le taux actuel de consommation n'excède pas quelque 4 kg de poisson par habitant, le déficit risque d'atteindre 500,000 tonnes en 1975, et 700,000 tonnes en 1985 si l'on ne prend pas de mesures pour accroître les captures nationales ou les importations. En outre, 80,000 tonnes supplémentaires de poisson seront nécessaires pour accroître la rentabilité des usines de transformation existantes. Sous l'effet conjugué de la croissance démographique, de l'industrialisation des pêcheries locales et de l'augmentation du PNB, la demande de poisson dans la région pourrait bien excéder 2 millions de tonnes en 1975/80. En revanche, l'augmentation projetée de la production halieutique dans des pays tels que le Sénégal exigera sous peu de nouveaux débouchés.

MESURES POUR AUGMENTER LA PRODUCTION

Un certain nombre de pays ont dressé des plans pour augmenter la production grâce à l'achat de bateaux, la création d'usines de transformation du poisson, l'expansion des installations actuelles d'entreposage frigorifique et de congélation et la construction de ports de pêche. La mise en oeuvre de ces nouveaux projets pourrait porter les captures à plus de 1,600,000 tonnes. Il faudrait investir pour les réaliser environ 200 millions de dollars E.-U.

Dans la plupart des pays, les bateaux de pêche en usage actuellement mesurent en moyenne 25 m pour une puissance de 300 CV. La plupart transportent de la glace, mais rares sont ceux qui disposent d'installations de congélation. Dans les régions septentrionales et méridionales du Golfe de Guinée, où l'on trouve tout au long de l'année de fortes concentrations de poissons, les bateaux semblent répondre aux besoins, bien qu'ils soient de construction ancienne. Dans certaines régions, il semble que les stocks commencent à s'épuiser et les flottilles de quelques pays plus développés vont pêcher au large de côtes éloignées où la pêche est plus rentable.

Selon les disponibilités en poisson, la tendance serait dans un proche avenir à la constitution de flottilles composées de chalutiers-congélateurs à grande autonomie et de senneurs à senne coulissante opérant au-delà de la zone côtière située entre le Cap Verga et le Cap Lopez. Le Ghana a déjà donné l'exemple et, plus récemment, une flottille de chalutiers de haute mer (70 m par 2000 CV) s'est constituée au Cameroun. On pourrait s'inspirer de l'expérience de ces pays en créant une flottille de pêche en eau profonde en Afrique occidentale.

A titre de mesure immédiate vers la réalisation de cet objectif, on pourrait promouvoir des techniques de chalutage en eaux moyennes, de façon à permettre aux chalutiers locaux d'opérer dans des eaux de plus de 70 m de fond vers le rebord du plateau continental. Ce genre de pêche expérimentale devrait être intensifié au long de la côte occidentale africaine.

Les flottilles de l'Afrique occidentale comptent actuellement 20 thoniers (clippers et senneurs), chiffre qui devrait pratiquement doubler au cours des prochaines années. On s'attend également à une plus grande participation des pêcheurs africains à la pêche à la canne et à l'hameçon à la suite de l'organisation de stages de formation et de démonstration. La pêche de la crevette prend également un rapide essor en Afrique occidentale grâce à la participation des capitaux étrangers.

On a envisagé récemment la création de complexes industriels pour le traitement du poisson au Ghana, au Gabon et au Congo Brazzaville, mais ce type d'entreprise de grande envergure risque de donner lieu à des difficultés, à moins que l'on s'assure au préalable de leur rentabilité par des études de viabilité. Sur les 7000 km de côtes qui bordent l'Afrique occidentale, seuls quelques pays disposent d'installations portuaires destinées aux bateaux de pêche: Mauritanie, Sénégal, Côte-d'Ivoire, Ghana, Dahomey et Cameroun. Dans les autres pays, on trouve uniquement des jetées privées ou des postes à quai mis occasionnellement à la disposition de ces bateaux dans les ports de commerce. Dans la plupart des cas, la barre rend l'accès à la côte difficile et ne permet pas la modernisation des pêches, sauf lorsqu'existent des abris. Un certain nombre de pays ont dressé des plans pour améliorer les installations en place ou construire de nouveaux ports de pêche.

Pour permettre aux pays d'Afrique occidentale de répondre à la demande croissante de poisson, des mesures devraient être prises pour accélérer l'industrialisation des pêcheries. On pourrait par exemple mettre en service des engins de pêche plus modernes — tels que chaluts flottants et chaluts de fond à grande ouverture — et constituer une flottille de pêche de haute mer ayant une forte capacité de charge. Il faudrait envisager simultanément la possibilité de mettre sur pied des industries halieutiques dans certaines régions. Toutefois, en raison de l'ampleur et de la complexité des problèmes posés par l'industrialisation des pêches, il conviendrait d'entreprendre des études an niveau régional afin d'examiner les incidences techniques, financières et juridiques des mesures envisagées.

Traitément et commercialisation du poisson

En 1969, l'Afrique occidentale a importé 200,000 tonnes environ de poisson — soit 500,000 tonnes de poisson congelé en provenance de navires affrétés et 120,000 tonnes de poisson traité — morues séchées d'Europe, sardines en boîte du Maroc et des îles Canaries, poisson séché-fumé d'Angola, de Zambie et autres pays limitrophes. Le commerce inter-régional s'est élevé à 100,000 tonnes, essentiellement sous forme de produits transformés en provenance de la Mauritanie, du Mali et du Tchad. Les principaux importateurs de poissons des pays africains et non africains pour la consommation locale ont été: le Congo Kinshasa (100,000 tonnes), le Nigeria (60,000 tonnes), le Ghana (20,000 tonnes), le Congo Brazzaville (17,000 tonnes) et la Côte-d'Ivoire (13,500 tonnes). Les principaux exportateurs dans la région du Golfe de Guinée ont été: la Mauritanie (36,000 tonnes), le Mali (30,000 tonnes) et le Tchad (16,000 tonnes). Certains pays tels que la Côte-d'Ivoire, le Togo et le Cameroun ont commencé à importer du poisson congelé. Pendant la dernière décennie, les importations de poisson congelé par bateaux affrétés russes, polonais et japonais, ont pris de l'expansion notamment au Nigéria, au Ghana, au Libéria et au Sierra Leone. Le poisson est débarqué dans des caisses de 20 à 30 kg et vendu 100 à 200 dollars E.-U. la tonne. Le plus souvent, il est vendu à des négociants traditionnels (fish mammies) qui le sèchent et le fument avant de le mettre en vente. Dans certains cas, il est transporté par route ou par chemin de fer jusqu'à l'intérieur du pays, où se trouvent des entrepôts frigorifiques. La commercialisation du poisson conservé dans la glace ou congelé débarqué par des bateaux qui ont un port d'attache local s'est développée récemment dans certains pays, notamment le Cameroun et la Côte-d'Ivoire. Bien qu'un réseau de commercialisation se soit constitué au Libéria, au Sierre Leone et, dans une certaine mesure, au Nigeria et au Ghana, les installations de commercialisation du poisson congelé sont encore insuffisantes. Le Congo Kinshasa s'était autrefois efforcé de développer la commercialisation du poisson congelé à partir de la région des lacs et il envisage actuellement de remettre en état et de prolonger sa chaîne du froid.

La consommation totale de poisson dans la région du Golfe de Guinée s'est élevée à environ 1,300,000 tonnes en 1969/70 — dont 360,000 tonnes de poisson frais et 930,000 tonnes de poisson traité. La consommation par habitant est de 10 kg. Les pays ayant un niveau élevé de consommation sont les suivants: Sénégal (40 kg), Congo Brazzaville (39 kg), Ghana (24 kg), Côte-d'Ivoire/Libéria/Guinée équatoriale (20 kg) et Mali (17 kg).

CONSERVATION DE POISSON

Le séchage, le fumage et le salage sont les procédés les plus communément employés pour conserver le poisson en Afrique occidentale, et c'est seulement en Mauritanie que les opérations de séchage et de salage sont effectuées à une échelle industrielle. Dans les autres pays, ces opérations restent au niveau de l'entreprise familiale. Le poisson est généralement fumé et séché sur des claies de bambou dans des sortes de hutte d'enfumage dont la capacité varie de 1 kg par jour (type "cuisine") à 90 kg par jour (type "beniboye" au Nigéria). Selon le degré d'humidité et le procédé employé, le produit peut être conservé pendant une période allant de quelques jours à plusieurs mois. Cependant, la détérioration due aux insectes est telle qu'après deux ou trois mois, environ un tiers du poisson est gâté. On estime à environ 30 millions de dollars E.-U. les pertes ainsi provoquées chaque année en Afrique occidentale.

COMMERCIALISATION

Le poisson est généralement transporté dans des sacs ou dans des paniers, par terre ou par voie d'eau, jusqu'à des distances de 100 km. Les intermédiaires — généralement "fish mammies" — contrôlent les échanges, ce qui décourage le plus souvent les pêcheurs. Ceux-ci manifestent très peu d'intérêt pour les programmes de mise en valeur des pêches, à moins de bénéficier d'une aide financière.

Alors que le commerce traditionnel des produits traités a fourni le débouché le plus important pour la consommation de poisson en Afrique occidentale, il est dans certains cas inefficace et préjudiciable aux pêcheurs. Il est en effet cause de gaspillage et fait monter le coût du produit. Dans de nombreuses régions, la consommation de poisson reste à un niveau très faible.

Les mesures ci-après pourraient améliorer le système actuel: promotion de la commercialisation de poisson congelé et frais avec amélioration du système traditionnel de commercialisation; amélioration des techniques de traitement du poisson et lancement de nouveaux produits; lutte contre les insectes; expansion des activités commerciales dans la région du Golfe de Guinée et à l'extérieur.

Le public africain accepte très volontiers le poisson congelé et le poisson frais et la réussite de tout projet visant à accroître la consommation de poisson congelé dans les régions de l'intérieur dépend essentiellement de l'existence d'un réseau routier approprié et d'installations d'entreposage frigorifique. L'amélioration de la manutention et de l'entreposage du poisson grâce à la mise en place d'une chaîne du froid abaisserait les prix à la consommation.

On envisage pour le lac Tchad la création d'usines de fabrication de la glace, ayant une capacité journalière de 5 tonnes de glace broyée. Un projet analogue est actuellement en cours d'exécution au Mali, où les poissons sont rassemblés dans les centres situés au long des fleuves dans des caisses isothermes remplies de glace. Le produit est entreposé à Mopti et dirigé sur les marchés éloignés dans des camions frigorifiques.

Trois centres pilotes existent depuis longtemps au Dahomey pour la revente directe du poisson aux consommateurs, tandis qu'au Nigeria l'on se propose de développer la commercialisation du poisson par la création de coopératives.

NOUVELLES TECHNIQUES DE TRANSFORMATION

Bien qu'elle ait été modeste, l'aide accordée au cours des dix dernières années aux pays d'Afrique occidentale en vue d'améliorer les techniques de transformation du poisson a donné des résultats encourageants chez les suivants: Ghana, Côte-d'Ivoire, Mauritanie, Nigéria, Tchad, Sénégal et Mali. De nouveaux types de séchoirs ayant une capacité et un rendement supérieur ont été mis en service. En Mauritanie, un laboratoire pour le contrôle de la qualité du poisson est en voie de création, et au Ghana un institut technologique alimentaire, comprenant un laboratoire pour la mise au point des produits de la pêche, a été créé avec l'aide du PNUD/FAO. Au Sénégal, une formation en matière de technologie du poisson est maintenant dispensée à l'école des pêches de Thiaroye.

En 1965, une technique de salage et de séchage du poisson a été mise au point au Tchad en vue d'une meilleure conservation des produits, notamment pour réduire les dégâts causés par les insectes. Les expériences réalisées dans ce pays, ainsi qu'au Cameroun et au Nigéria, ont remporté un grand succès et les pêcheurs sont prêts à adopter les nouvelles techniques si des dispositions sont prises pour ramasser et commercialiser leurs prises.

Les résultats obtenus par le spécialiste FAO de traitement du poisson au Mali, qui s'est efforcé de diversifier la production halieutique, méritent une attention particulière. Le spécialiste a mis au point une technique consistant à fumer à froid la perche du Nil pour obtenir un produit analogue au saumon. Il a fabriqué également des rollmops, de la salade de poisson, etc. Une petite conserverie a été créée pour la production expérimentale de poisson en conserve imitant la sardine ou le thon à partir des espèces *Alestes*, *Lates niloticus* et autres. Les essais d'acceptation par les consommateurs ont été favorables pet les êcheries du Mali pourraient se développer à un rythme plus rapide au cours des prochaines années si l'on pouvait fabriquer et commercialiser les nouveaux produits à une plus vaste échelle. Il conviendrait de faire des efforts dans le domaine de la publicité et de l'exportation.

Le coût des récipients a empêché jusqu'à présent de nombreux pays en voie de développement de se lancer dans la conserverie du poisson. Cette difficulté pourrait être surmontée par l'emploi de conteneurs semi-rigides à la place des boîtes métalliques.

Les techniques de désinfestation mises au point par l'expert de la FAO au Mali ont donné de bons résultats. Plusieurs types d'insecticides ont été expérimentés, et le Therposac a été recommandé en dilution à 0,7%. Sur la base de suggestions formulées par l'expert, un programme de désinfestation a été mis en oeuvre par le Gouvernement. L'expert a également conçu un système de four solaire en vue de son application au niveau des petites exploitations.

Conclusions

La promotion et la diffusion des nouvelles techniques de traitement et de commercialisation sont d'importance primordiale pour l'accroissement de la consommation de poisson dans les pays d'Afrique occidentale. Une action soutenue est nécessaire pour rehausser les normes et améliorer les compétences des fabriquants. Pour parvenir à cette fin, on devrait adopter les mesures ci-après:

(a) Octroi d'une aide aux instituts et aux laboratoires s'occupant de la technologie du poisson et des denrées alimentaires pour la mise au point de nouveaux produits, l'amélioration des techniques de conservation, de réfrigération, d'entreposage et de conditionnement et la réduction des pertes.

(b) Création, dans le cadre d'un institut s'occupant des denrées alimentaires en général, d'un laboratoire spécialisé dans les produits halieutiques, dont le programme d'action serait exécuté sous la direction du fonctionnaire gouvernemental responsable du développement des pêches. Etant donné que les problèmes posés par la conservation et l'utilisation du poisson sont identiques dans de nombreux pays, la coordination entre pays d'une même région devrait aboutir à la mise au point de programmes mixtes, bénéficiant de conseils techniques accordés au titre de l'aide internationale ou bilatérale.

(c) Création, dans certaines régions, de centres chargés d'aider au rassemblement, à l'entreposage, au traitement et à la commercialisation des produits. De tels centres pourraient contribuer à rehausser la qualité de la pêche artisanale grâce à des démonstrations et à des stages de formation concernant les techniques halieutiques, la manutention et le traitement du poisson, la manoeuvre des embarcations motorisées, ainsi que par la création de coopératives.

(d) Intensification des échanges inter-régionaux. Bien que la production de poisson soit actuellement importante dans la région du Golfe de Guinée, la population de l'Afrique occidentale (plus de 80 millions de personnes) est encore insuffisamment approvisionnée. Il est donc urgent d'intensifier les échanges inter-régionaux afin de réduire les importations venant des pays qui n'appartiennent pas à la région. Les politiques des prix pour les produits destinés à remplacer des importations ou pour la commercialisation sur une échelle régionale exigent des accords inter-régionaux. Il y a lieu d'entreprendre une étude régionale pour analyser ces aspects et envisager les mesures susceptibles d'augmenter la consommation de poisson.

Ressources

Du Cap Blanc (20°N) au Cap Frio (15°S), la faune est homogène et se compose d'espèces tropicales. Cette région présente une caractéristique hydrologique très importante pour le poisson, à savoir l'existence de trois zones d'upwelling saisonnier, les zones septentrionale et méridionale étant les plus riches: Du Cap Blanc (20°N) au Cap Verga (10°N); Du Cap Palmas (8°W) au troisième méridien Est; Du Cap Lopez (Equateur au Cap Frio (15°S).

Dans les zones situées entre ces upwellings, les eaux côtières de surface sont peu productives.

Le plateau continental au-dessus duquel se concentrent les ressources les plus importantes (à l'exception des thonidés) constitue une bande étroite le long de la côte (environ 30 milles). Dans certains endroits — notamment au large de la Côte-d'Ivoire, du Togo et du Dahomey — sa largeur n'excède même pas 10 milles. Cependant, en certains points — en particulier du Cap Vert (Sénégal) à l'Ile Sherbro (Sierra Leone) — il s'étend sur plus de 100 milles de largeur. Il est difficile d'évaluer le potentiel des différents stocks, en raison du grand nombre d'espèces recontrées dans cette région. Les stocks démersaux sont plus riches à proximité de la côte (0–35 m de profondeur) et, dans une moindre mesure, près du plateau continental

(70–120 m), où l'on trouve des bancs pélagiques de sardines à proximité des fonds. Les stocks côtiers comprennent une grande variété d'espèces: ombrines (sciaenidés), mérous (serranidés), barbues (polynémidés), poissons-chats (ariidés) sparidés, raies, etc. Le rendement maximum de ces terrains de pêche a été estimé à environ 23 kg par ha et par an. Ce chiffre est supérieur dans certaines zones, notamment dans l'embouchure du Congo, où les eaux du fleuve fournissent un apport important.

Plus au large, la biomasse des poissons d'importance commerciale commence par décroître, puis augmente à nouveau à des profondeurs allant de 7 à 120 m, avec des espèces telles que les sparidés, *Argyrosomus nibe* et *Brotula paracubiceps*. A ces profondeurs, on trouve souvent près du fond des espèces pélagiques telles que le maquereau espagnol et les chinchards.

Les terrains riches en crevettes roses se trouvent à proximité des embouchures fluviales et à l'entrée des lagunes, et la pêche en eau profonde a récemment été entreprise au sud et au nord du Golfe de Guinée. On ignore encore le potentiel des stocks non exploités de petites crevettes à proximité du rivage.

Les stocks pélagiques de la zone comprennent des espèces côtières telles que le bonga et la sardinelle, et des espèces du large telles que les chinchards, tandis que les sardinelles rondes et le maquereau espagnol se rencontrent aussi bien dans les eaux côtières de surface qu'au large, à différentes profondeurs. Les principales ressources se trouvent dans les zones d'upwelling, parmi lesquelles la zone septentrionale (de la Mauritanie à la Guinée) et, dans une moindre mesure, la zone méridionale (du Gabon à l'Angola) sont les plus riches. Le potentiel le plus important est représenté par les sardinelles rondes. Le développement récent de la pêche dans la zone septentrionale d'upwelling a démontré l'existence d'importantes ressources au large de la Mauritanie et du Sénégal. Ce développement ayant commencé seulement en 1970, on dispose de peu de données pour en estimer le potentiel, mais les chiffres enregistrés pour le nombre total de bateaux de pêche en activité et pour le total des captures en 1970 indiquent que le niveau atteint depuis deux ans est bien supérieur à ce qu'il était auparavant.

Les sardinelles plates sont plus abondantes dans les zones d'upwelling saisonnier, leurs bancs se situant à une profondeur de 30 m. Les principaux stocks se trouvent au large du Sénégal, de la Guinée et du Sierra Leone dans le nord, et au large du Gabon, du Congo et de l'Angola septentrional dans le sud. Les stocks situés au large de la Côte-d'Ivoire, du Ghana, du Togo et du Dahomey sont probablement moins importants (environ 10,000 tonnes). Le bonga, dont le potentiel est plus réduit, constitue la principale ressource pélagique du Sierra Leone, du Libéria, du Nigéria et du Cameroun. Les bancs se déplacent au large et près des embouchures fluviales en suivant les crues. L'albacore, le thon obèse et la bonite à ventre rayé abondent dans les eaux de surface au delà du plateau continental, dans les trois zones d'upwelling saisonnier ainsi qu'à proximité des Canaries et des îles du Golfe de Guinée.

A la suite des prospections, effectuées conjointement par plusieurs pays dans le Golfe de Guinée au cours de la dernière décennie et après analyse des statistiques des captures et de l'effort de pêche, l'inventaire des ressources est devenu bien plus précis. L'exploitation des stocks par des bateaux de pêche industrielle a pris beaucoup d'ampleur, passant d'un volume de 350,000 tonnes en 1960 à quelque 1,5 ou 2 millions en 1970; on a ainsi excédé les potentiels de certains stocks — tels que les sparidés au large de la côte nord-ouest, quelques stocks démersaux côtiers et les stocks de sardinelles qui se trouvent au large de la Côte-d'Ivoire et (peut-être) du Ghana. On ne pourra poursuivre l'exploitation au rythme actuel sans excéder rapidement les rendements maximums des stocks les plus riches, tels que ceux de poissons pélagiques de la zone septentrionale. Les risques d'épuisement des ressources sont encore plus graves dans la zone équatoriale, où le potentiel halieutique est limité. Il convient de procéder à des analyses quantitatives et à des études sur l'évolution des stocks (importance et composition) qui font actuellement l'objet d'une exploitation intense.

En raison des problèmes posés actuellement par l'aménagement international des pêches dans la région, il faudrait disposer d'un plus grand nombre de données sur les modes migratoires, comme sur l'identification et le mélange des stocks. Il y a lieu également de mener un plus grand nombre d'enquêtes sur certaines espèces — notamment crevettes et anchois — pour lesquelles on manque de renseignements. Les statistiques relatives aux captures et à l'effort de pêche et aux données biologiques devraient porter sur toute la zone et être tenues régulièrement afin d'assurer un contrôle permanent des effets de l'exploitation sur les stocks. Les plans élaborés au niveau régional devraient prévoir une coopération avec les laboratoires existants et l'octroi d'une aide à ces derniers, ainsi que la création de nouveaux laboratoires dans des pays tels que le Cameroun et la Mauritanie, qui envisagent de mettre en valeur le secteur halieutique.

Pisciculture en eau douce et en eau de mer

Des études effectuées en Asie, en Afrique orientale et aux Etats-Unis sur l'élevage du chanos, du poisson-chat et du tilapia ont fait apparaître que l'on pouvait obtenir un profit net de 15 à 20% des investissements effectués dans des étangs d'une superficie d'environ 10 ha. Alors que 1 ha de pâturages de bonne qualité ne peut produire que quelques quintaux de viande de boeuf, il est possible, avec la même superficie, de produire une tonne de poisson, voire davantage. L'emploi de techniques sélectionnées et d'aliments artificiels permet d'accroître de façon notable les rendements en poisson.

Jusqu'en 1960, des efforts considérables ont été faits au Congo Kinshasa pour développer la pisciculture, et des rendements de 7 tonnes à l'hectare ont été atteints en certains endroits. Les Gouvernements du Libéria, de la Côte-d'Ivoire, du Nigeria et du Cameroun se sont également efforcés de développer cette activité au cours de la dernière décennie. En décembre 1967, on a mis en oeuvre un projet PNUD/FAO pour contribuer à l'expansion et au développement de la pisciculture en République Centrafricaine, au Gabon, au Congo Brazzaville et au Cameroun, en effectuant des travaux de recherche appliquée et en formant des fonctionnaires des pêches qualifiés et des vulgarisateurs dans quatre centres (Landja, Oyem, Djoumouna et Foumban). A la suite du succès remporté par ce projet, il est actuellement prévu d'associer les activités de recherche appliquée et de formation à des travaux pratiques, ce qui permettra aux fonctionnaires ainsi formés (a) d'aider les pisciculteurs, et (b) de créer des centres pilotes gérés sur une base commerciale qui puissent éventuellement devenir autonomes.

La bande côtière située en bordure du Golfe de Guinée est constituée, sur environ 2 millions d'hectares, de lagunes et de marécages. La zone marécageuse est particulièrement étendue dans le Delta du Niger (environ 800,000 ha). Le sol des mangroves où s'est accumulé du sulfate libre s'acidifie en se desséchant sous l'effet de l'oxydation aérobie, de sorte que les marécages ne sont guère utilisés pour la culture du riz ou à d'autres fins agricoles. Ils conviennent toutefois à la pisciculture et, en 1964, on a créé une ferme expérimentale à Buguma (près de Port Harcourt) pour démontrer qu'il était possible d'élever des poissons en eau saumâtre grâce à des techniques de culture appropriées. On estime que l'on pourrait ainsi exploiter dans cette zone environ 400,000 ha, dont le rendement annuel pourrait atteindre 200,000 tonnes de poisson. La meilleure façon de gérer de vastes établissements piscicoles en eau saumâtre serait, pense-t-on, de recourir à des coopératives bénéficiant du soutien d'un service de vulgarisation bien organisé et disposant de matériel pour la construction des étangs, ainsi que pour la conservation et l'entreposage du poisson. On pourrait cultiver les expèces suivantes: mulet ramada, poisson-chat, carpe commune et crevette.

La pêche lagunaire tient une place importante dans les pêcheries artisanales du Nigéria, du Dahomey et de la Côte-d'Ivoire. Au Nigéria occidental, les lagunes couvrent une superficie d'environ 500,000 ha, et leur production est estimée à 10,000–12,000 tonnes. Au Dahomey, les captures faites dans les lagunes sont tombées, de 25,000 tonnes en 1960, à 12,000 tonnes en 1970 en raison des changements survenus dans les conditions du milieu. L'entrée et la sortie d'eau de mer et d'eau douce dans la lagune a fortement nui aux populations de *Tilapia* et des térédos sont apparus, causant des dégâts considérables aux pièges locaux fabriqués en bois (Acadja).

Environ 110,000 ha de lagunes sont jugés aptes à la pisciculture en Côte-d'Ivoire. Leur production actuelle n'excède pas 5000 tonnes par an environ. En 1969, une station expérimentale pour la culture des crevettes a été créée à Grand Bassam et des conduites ont été mises en place pour approvisionner les réservoirs en eau de mer. Dans cette station, on applique la technique Fujinaga à l'élevage des crevettes. Des expériences consistant à cultiver des *Tilapias* dans des parcs établis à l'intérieur des lagunes ont également donné des résultats satisfaisants.

Bien que l'aquiculture marine en soit encore à ses débuts, le potentiel de production est élevé. En Afrique occidentale, les lagunes et les eaux saumâtres sont essentiellement situées dans les pays de Golfe de Guinée, dont le plateau continental a une faible productivité et dont les ressources s'épuisent à la suite d'une pêche intensive. Cent-soixante mille pêcheurs environ et leurs familles vivent de la pêche dans les lagunes et dans les marécages. Au Dahomey, le pêche lagunaire constitue une activité de base pour plus de 20,000 personnes. Le volume des prises ne cesse de diminuer et il en sera ainsi jusqu'à ce que des mesures soient prises pour relancer les pêcheries. Le rendement moyen des pêches lagunaires ne semble pas dépasser actuellement 25 kg/ha, mais il pourrait atteindre jusqu'à 3 tonnes/ha en cas d'élevage intensif.

Etant donné l'intérêt qu'il y aurait à développer ces pêcheries, il conviendrait de faire un inventaire des lagunes d'eaux saumâtres et des marécages et d'entreprendre des études approfondies dans les domaines ci-après: amplitude des marées, variations de la salinité, sources d'eau douce, conditions pédologiques, disponibilités en matériel d'empoissonnement, pollution, espèces les mieux adaptées à la pisciculture et aspects économiques du développement de l'aquiculture. Il faudrait encourager la création de stations expérimentales et s'efforcer d'acclimater des espèces inconnues actuellement en Afrique occidentale. Des opérations pilotes devraient être associées à la recherche et à la formation de personnel local. Simultanément, on ne devrait épargner aucun effort pour stimuler la pisciculture en eau douce par des programmes de formation, de recherche et de démonstration pratique, compte tenu de l'expérience acquise et des techniques mises au point par le projet régional de pisciculture (AFR/REG 54) à Bangui.

Formation

L'insuffisance du personnel employé dans les services des pêches et l'absence de main d'oeuvre qualifiée pour assurer le fonctionnement des bateaux de pêche modernes comptent parmi les obstacles les plus sérieux au développement dans la plupart des pays d'Afrique. La FAO a donc entrepris un certain nombre d'études sur l'enseignement halieutique — dont trois dans les pays africains en 1965–67 — et elle a formulé des recommandations visant à aborder les problèmes de formation dans une optique régionale. Elle a fait valoir que la formation sur une vaste échelle dans les pays développés d'étudiants en provenance des pays en voie de développement constituait une méthode coûteuse et peu réaliste. Elle a suggéré que l'on renforce certains établissements d'Afrique afin de répondre aux besoins d'un certain nombre de pays en matière de formation et qu'on leur accorde un soutien adéquat notamment par l'octroi de bourses.

L'Afrique occidentale compte plusieurs écoles ou centres qui dispensent une formation halieutique ou pourraient le faire: Le Centre de formation professionnelle Mamadou Touré, en Mauritanie; L'Ecole nationale de formation maritime et l'Ecole d'administration des pêches maritimes du Sénégal, à Thiaroye (Sénégal); Le Centre de formation maritime professionnelle d'Attiécoube et le Centre de formation piscicole de Bouaké, en Côte-d'Ivoire; Le "Nautical College" du Ghana; La "Federal Fisheries School" de Lagos, au Nigéria; Le Centre technique forestier tropical, de Fort-Lamy (Tchad); Le Centre régional de formation en pisciculture du projet PNUD/FAO AFR/REG 54 — pisciculture, formation et recherche, à Bangui (République Centrafricaine); Les sous-stations du Centre régional de formation en pisciculture AFR/REG 54, au Cameroun, au Congo Brazzaville, et au Gabon.

Les progrès actuels de l'industrialisation et les changements économiques survenus dans la structure des pêcheries ont fait apparaître plus clairement dans les pays en voie de développement l'insuffisance des services des pêches au niveau supérieur, ainsi que la pénurie d'agents de vulgarisation au niveau des pêcheurs. De telles lacunes retardent le progrès. Il est également urgent que les gouvernements envisagent dans leurs plans l'industrialisation des pêches par la formation intensive de maîtres-pêcheurs, d'ingénieurs navals et d'autres travailleurs qualifiés. La formation à tous les niveaux, notamment par l'intermédiaire des services de vulgarisation et des autres services gouvernementaux, est indispensable à la poursuite du progrès. La mise au point de tels programmes peut se fonder sur les rapports établis par les experts conseils de la FAO, et sur les recommandations qu'ils contiennent.

Les problèmes de développement de petites organisations de pêche[1]

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Les petites organisations sont un moyen effectif, pour les pêcheurs artisans, d'accéder à des éléments de progrès dont ils sont traditionnellement exclus. Elles doivent réaliser un "pont institutionnel" entre une pêche de subsistance et une activité économique moderne.

Les petites organisations doivent assurer la relève des structures communautaires traditionnelles — en particulier le village — afin de permettre l'ouverture au progrès. Elles offrent une structure d'accueil à des éléments de modernisation qui sont le plus souvent étrangers aux coutumes anciennes.

La pêche est marquée de nombreux particularismes qui imposent une approche sectorielle et intégrée de ses problèmes. Elle ne réalise que des équilibres précaires dans le cadre d'une crise endémique qui impose aux petites organisations d'urgents problèmes de décision.

Le financement des bateaux est un problème majeur pour toute pêche artisanale. Il impose une étroite coordination entre collecte des ressources et politique d'investissement, qui n'est réalisable qu'à un stade relativement avancé de développement dans le cadre d'une organisation de crédit.

Il existe dans toutes les régions — même pauvres — une épargne latente. L'organisation de crédit doit fournir le canal institutionnel nécessaire à sa collecte et à sa transformation en investissements productifs. Ses ressources peuvent être complétées par des avances d'Etat ou des aides internationales.

Les organisations de pêche ont besoin, pour se développer, de bases légales et d'outils juridiques. La création d'une institution spécifique englobant l'ensemble des éléments de développement est à conseiller. Dans la pratique, cette institution peut s'organiser autour du crédit ou de toute autre fonction.

La voie fédérative convient parfaitement au développement de petites organisations de pêche. L'importance des besoins de services, en amont comme en aval, impose une politique d'intégration verticale qui se complète par des intégrations horizontales au niveau régional et au niveau national. Des ensembles polyvalents intégrés concentrent alors le pouvoir compensateur des pêcheurs artisans.

Cette forme complexe de développement impose un travail constant de recherche, de réflexion, d'incitation et d'encadrement. En un premier stade, ce rôle peut être assuré par une institution consciente de cette fonction synthétique pour créer les nouvelles structures économiques.

Ce peut être, dans un tel cas, l'organisation de crédit qui assurera par la suite la fonction de contrôle.

Le cadre humain de la pêche artisanale est très particulier. Il est marqué par l'indisponibilité et l'indépendance des hommes. Les modifications profondes de mentalité que nécessite le développement ne peuvent être obtenues que par des programmes de formation intégrés à la vie du village.

Les besoins sociaux des marins/pêcheurs sont pratiquement illimités. La petite organisation de pêche peut étendre sa gamme de services à tous les aspects de leur vie professionnelle ou familiale. Cette voie l'amène le plus souvent à reconsidérer en totalité l'organisation de la pêche et les habitudes traditionnelles d'exploitation. Des expériences "pilotes" doivent infléchir peu à peu ces habitudes, et aboutir à des formes plus modernes de travail et de vie.

Small-scale organizations are effective channels through which small fishermen ("pêcheurs artisans") can gain access to factors of production making for progress traditionally beyond their reach. Institutionally speaking, what is needed is to "build a bridge" between subsistence fisheries and a modern industry, something that small fishermen's organizations can do.

Such organizations should relieve traditional community structures, in particular the village, in order to open the road to progress. They can provide a framework into which factors making for modernization — usually foreign to old customs — may be fitted.

Because of certain unique features, fisheries require a sectorial and integrated approach to their problems. They generally achieve only a precarious equilibrium in an atmosphere of constant crisis placing small organizations under the obligation of making emergency decisions.

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[1] Préparé en vue de la "Conférence d'experts sur l'aménagement et le développement des pêches," de l'Organisation des nations unies pour l'alimentation et l'agriculture, tenue à Vancouver, C.-B., Canada, 13–23 février 1973.

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Finding financing for boats is a major problem for all small-scale fishing. It necessitates close coordination between the assembly of resources and the policy of investment, which is only feasible at a relatively advanced stage in development and with the help of a credit organization.

Everywhere, even among the poorest groups, there are latent possibilities for savings. The credit organization should constitute the institutional channel for the collection of savings, to be converted into productive investment. Fishermen's savings can be supplemented by government advances or international aid.

In order to develop, fishermen's organizations need legal foundations and instruments. It is advisable to create special institutions capable of embracing all development factors. In practice, such institutions can be organized around credit agencies or around bodies with other pertinent functions.

Another suitable means for development of small-scale fishermen's organizations is through federation. The scope of requirements for services of all kinds, both pre and post-fisheries, is such as to impose a policy of vertical integration supplemented by regionwide or nationwide cross-integration. Integrated, multipurpose groupings would concentrate the financial power of small fishermen.

Such a complex approach to development necessitates constant research, reflection, proffering of incentives, and manpower training. In the first stage this work can be done by some institution that is conscious of this function of synthesis leading to the creation of new economic structures. In such a case, the credit organization may subsequently assume responsibility for control work.

The human factor in small-scale fisheries is unique, the people exhibiting great independence of spirit and reserve. The profound recasting of their mentality, a pre-requisite for development, can only be accomplished through manpower training programs integrated into village life.

The social needs of seamen/fishermen are practically unlimited. Small fishermen's organizations can expand their range of services to all aspects of working and family life. As a rule, this approach will lead the fishermen to reconsider the whole organizational setup of fisheries and of traditional fishing practices. Pilot experiments should be aimed at gradually changing old habits and modernizing both the way of life of the fishermen and the fisheries themselves.

Para los pescadores artesanos, las pequeñas organizaciones son un medio eficaz para lograr acceso a elementos de progreso de los que están tradicionalmente excluidos. Las pequeñas organizaciones deben tender un "puente institucional" entre la pesca de subsistencia y la actividad económica moderna.

Las pequeñas organizaciones deben dar el relevo a las estructuras comunitarias tradicionales, en especial la aldea, para permitir así una abertura al progreso. Ofrecen una estructura para acoger elementos de modernización casi siempre extraños a las costumbres tradicionales.

La pesca se caracteriza por diversas peculiaridades, que hacen necesario abordar sus problemas en forma sectorial e integrada. No consigue más que equilibrios precarios dentro de una crisis endémica que impone a las pequeñas organizaciones urgentes problemas de decisión.

La financiación de las embarcaciones es un problema importante en toda pesquería artesanal, que obliga a coordinar estrechamente la explotación de los recursos y la política de inversión, cosa no realizable más que en una fase relativamente avanzada de desarrollo y dentro del marco de una organización de crédito.

En todas las regiones, incluso en las pobres, existe un ahorro latente. La organización de crédito debe ofrecer el canal institucional necesario para recoger ese ahorro y transformarlo en inversiones productivas. Sus recursos peuden completarse con anticipos estatales o ayuda internacional.

Para desarrollarse, las organizaciones pesqueras necesitan bases legales e instrumentos jurídicos. Es aconsejable la creación de una institución específica que englobe todos los elementos del desarrollo. En la práctica, esta institución puede organizarse en torno al crédito o cualquier otra función.

La vía federativa se adecua perfectamente al desarrollo de las pequeñas organizaciones pesqueras. La importancia de las necesidades de servicio, tanto ascendiendo como descendiendo a lo largo de la cadena de producción, impone una política de integración vertical completada mediante integraciones horizontales en el plano regional y nacional. De esa forma se concentra el poder compensador de los pescadores artesanos mediante conjuntos polivalentes integrados.

Esta forma compleja de desarrollo impone una actividad constante de investigación, reflexión, incitación y encuadramiento. En la primera fase, esta función puede correr a cargo de una institución consciente de esta función sintética para crear las nuevas estructuras económicas.

En este caso, puede ser la organización de crédito quien posteriormente se encargue de la función de control.

El marco humano de la pesca artesanal es muy peculiar. Se caracteriza por la indisponibilidad y la independencia de las personas. Las modificaciones profundas de mentalidad que son necesarias para el desarrollo no pueden obtenerse más que mediante programas de formación integrados en la vida de la aldea.

Las necesidades sociales de los pescadores son prácticamente ilimitadas. Las pequeñas organizaciones pesqueras pueden extender sus servicios a todos los aspectos de su vida profesional o familiar. Esta vía lleva, casi siempre, a examinar de nuevo en su totalidad la organización de la pesca y las costumbres tradicionales de explotación. Mediante experiencias "piloto" se deben modificar poco a poco estas costumbres, para encontrar formas más modernas de trabajo y de vida.

Dans la plupart des pays, la pêche artisanale sort tout juste d'une économie de subsistance et les politiques nationales menées en vue de son développement rencontrent de nombreuses difficultés. En effet, l'imbrication de facteurs économiques et sociaux complexes rend malaisé l'établissement de programmes suffisamment intégrés pour prendre en compte les aspects multiples d'un même problème. De plus, la pêche se prête particulièrement mal aux expériences de planification directe, du fait que l'immense majorité des marins demeure totalement au dehors des courants de progrès technique ou économique, qui viennent irriguer les autres secteurs.

Accéder à ces courants, connaître et utiliser les moyens économiques, financiers, techniques, juridiques qui sont à la base de tout développement, de tout système moderne d'exploitation, tel est le problème majeur des populations qui tirent leur revenu de la pêche. Elles doivent pouvoir aboutir à des formes d'organisations intégrées, capables d'assumer les fonctions administratives et commerciales nécessaires à une pêche en progrès; elles doivent, pour ce faire, passer un certain nombre de "seuils" mentaux leur permettant de déborder progressivement le cadre immuable de leur activité traditionnelle.

Cette promotion collective réclame elle-même la création d'institutions de développement, capables de remplacer ou de compléter des organisations sociales traditionnelles comme le village de pêcheurs, où vie économique et vie sociale s'imbriquent profondément dans le cadre d'un système qui ne vise que la subsistance de la communauté. L'apparition du progrès technique, la rapide évolution du mode de vie conduisent à la nécessité de trouver de nouvelles structures communautaires qui, dans la pratique, viennent remplacer le village et font figure de pont institutionnel entre une pêche de subsistance et une pêche moderne et progressive.

Ceci est le rôle des petites organisations de pêche, cellules communautaires de base dont la forme peut être coopérative, syndicale ou corporative. Structures d'adaptation, elles permettent l'accès au progrès de gens qui en étaient traditionnellement rejetés; elles se présentent en cela comme un relais indispensable à toute planification moderne. Leur développement se confond étroitement avec celui de la pêche artisanale.

Problèmes Spécifiques du Développement de la Pêche Artisanale

Le développement de la pêche artisanale doit être envisagé d'un point de vue sectoriel: à bien des égards en effet, la pêche présente des caractères originaux, qui ne l'apparentent à aucune autre branche de la planification nationale. Dès les premiers stades du développement, elle apparaît comme un secteur à part, et les organisations de pêche, dont le rôle est précisément de se rattacher aux courants du progrès économique général, devront limiter de nombreux particularismes.

Situation de crise permanente

Au stade même de leur création, les petites organisations de pêche se trouvent confrontées à d'urgents problèmes de décision liés à une situation de crise permanente. Cette pression des évènements favorise leur constitution et leur progression rapide, mais elle est aussi une cause particulièrement redoutable de fragilité et de déséquilibre. Due à l'évolution générale des conditions d'exercice de la pêche, cette crise connaît des allègements ou des aggravations en un lieu ou dans un temps donné, mais elle n'en revêt pas moins un caractère endémique ou tendanciel. Son empreinte reste profonde dans tout le milieu maritime.

Le problème dominant de toute économie des pêches est la fragilité du capital et de l'exploitation pour les raisons suivantes:

(i) Un bateau suppose avant tout un investissement très lourd; son entretien est coûteux, son usure rapide, et sa production annuelle est généralement inférieure au coût initial. Cette faible rotation des capitaux place la pêche motorisée, dans quelque pays que ce soit, parmi les industries lourdes.

(ii) La valeur produite n'a aucun rapport direct avec le coûts de production et subit les doubles aléas du milieu et des marchés.

(iii) La pêche est donc infiniment plus fragile que l'agriculture: il n'y a pas de fonds de terre permanent et indestructible conservant sa valeur et sa productivité au-delà de toutes les crises; le capital doit être, au contraire, constamment renouvelé, tout fléchissement du flux d'investissements devant se traduire par une détérioration rapide du potentiel productif. Cette détérioration diminue d'autant la rentabilité et ne peut elle-même que concourir à aggraver le phénomène de désinvestissement.

(iv) A la lourdeur du capital s'ajoute une inertie considérable: les bateaux n'ont en général qu'une marge de choix limitée dans le type de pêche qu'ils peuvent exercer, et les reconversions sont souvent particulièrement difficiles. Cette contradiction entre un capital rigide et des conditions d'exploitations fluctuantes rend les marins/pêcheurs particulièrement sensibles à une conjoncture qui est une des plus imprévisibles et des plus contraignantes qui soient, tant par le manque de contrôle du milieu marin que par l'absence de toute maîtrise des marchés.

(v) La pêche subit enfin un phénomène mondialement connu, la détérioration à long terme des activités situées dans un cadre biologique: avilissement des cours du poisson par rapport aux prix des bateaux; progrès technique, dont le coût se montre très supérieur aux gains de productivité qu'il autorise. Il en résulte une véritable perte de substance.

Déséquilibres latents

L'acte de production est instantané. Avant comme après, l'activité de pêche est tributaire de services et d'infrastructures, aussi faible que soit son degré de développement. Cette situation la rend particulièrement vulnérable. Chaque petit port isolé réalise un équilibre économique précaire entre activités à terre et activitités à la mer, le ralentissement des unes pouvant provoquer l'écroulement des autres. C'est ainsi que la fermeture d'une conserverie peut priver tout un port de ses débouchés et que, de même, le désarmement de quelques bateaux peut faire disparaître les commercants les plus marginaux. Dans ces équilibres précaires, toute modification, même légère, des données, peut entraîner l'écroulement général du système. Les rivalités, les divergences d'intérêt, ne peuvent qu'augmenter cette fragilité.

Aussi la notion d'équilibre est-elle prédominante en matière de pêche. Les petites organisations de pêche doivent consolider, modifier, recréer des équilibres dont dépend leur développement; plus que partout ailleurs elles devront intervenir en amont ou en aval de la pêche, tant la rentabilité du bateau est tributaire des possibilités commerciales d'écoulement, ou du prix et de la qualité des fournitures. Ce souci d'équilibre doit se retrouver au niveau de la planification nationale qui doit harmoniser au mieux des investissements aussi divers que ports, installations frigorifiques, marchés, etc. L'économie des pêches n'est en fait que l'équilibre de ces multiples fonctions.

Milieu humain

Pour les petites organisations de pêche, l'adaptation des mentalités traditionnelles aux contraintes du progrès est rendue particulièrement difficile par l'indisponibilité liée au mode de vie des marins/pêcheurs.

Le bateau apparaît, le plus souvent, comme l'unité d'exploitation irréductible, en rivalité aigüe avec le restant de la flotte. L'esprit communautaire reste limité au bord qui représente une frontière humaine et morale autant qu'un atelier de production: à terre, les hommes restent traditionnellement isolés et dispersés. Ces rivalités se retrouvent entre les ports dont les relations sont souvent d'autant plus tendues qu'ils sont géographiquement proches les uns des autres.

Les conditions habituelles de la pêche, qui s'exerce en milieu complexe et contrôlé, à bord de petites unités autonomes, font que les patrons/pêcheurs demeurent fondamentalement indépendants. Non pas individualistes mais indépendants, ce qui se traduit avant tout par des réactions très particulières en matière de décision: le marin n'entreprendra rien, ne subira rien, sans en avoir compris et reconnu le bien-fondé.

Ces particularités de la pêche artisanale montrent combien est nécessaire une approche intégrée des problèmes; aussi bien pour les planificateurs que pour les petites organisations de base. Equilibre économique, facteurs sociaux et culturels doivent pouvoir être appréhendés globalement. Cette contrainte, en particulier, condamne les petites organisations de pêche à un rapide élargissement de leur domaine d'action.

Elements du Développement de Petites Organisations de Pêche

Technique juridique et institutions

Les petites organisations de pêche peuvent se créer de façon spontanée, au gré des circonstances locales. Mais, comme toutes les affaires, elles ont besoin, pour fonctionner, d'un cadre légal de fonctionnement, d'une technique juridique leur permettant d'organiser, de façon stable et durable, les efforts de leurs sociétaires pour vivre mieux. Le plus souvent, cette technique juridique est celle de la coopérative, forme d'organisation qui concilie au mieux les exigences parfois contradictoires du développement collectif et qui bénéficie de nombreuses expériences. Mais cette technique n'a rien d'exclusif. Le problème majeur est de fournir aux dirigeants des organisations de pêche, les outils juridiques adaptés à leurs besoins de développement et de créer des structures communautaires capables de faire accéder leurs membres à une économie progressive.

La petite organisation de pêche devra passer des contrats, constituer des réserves, investir, défendre ses activités contre la conjoncture ou contre les hommes. Les moyens légaux dont elle dispose conditionnent son succès. Or, le plus souvent, elle a des besoins très particuliers que peut ignorer le cadre juridique général qui régit les activités voisines. Elle risque alors de se voir limitée dans son développement, soit par le manque d'outils juridiques adaptés, soit au contraire parce qu'elle butte contre des barrières légales.

La bonne solution réside, le plus souvent, dans la création d'une institution adaptée aux problèmes propres de la pêche. Il n'est plus besoin de prouver combien une institution de développement peut aider un secteur que sa particularité tient à l'écart des grands courants du progrès économique. L'institution doit être à la fois un ensemble cohérent d'outils juridiques et une structure d'organisation des entreprises. Créée par l'Etat, avec des dispositions parfois dérogatoires à celles du droit commun, elle est destinée à canaliser et coordonner les efforts des organisations de pêche. Elle doit toutefois conserver une réelle souplesse et, en particulier, éviter les écueils de la réglementation abusive. Les besoins juridiques évoluent en effet de façon constante au fur et à mesure du développement, alors que les règlements sont, par nature, inamovibles et permanents. Il est de fait très courant de les voir limiter le développement des activités qu'ils concernent.

Le cadre de l'institution répond alors parfaitement au besoin d'une approche intégrée des problèmes de la pêche. Moyen de développement rapide pour les petites organisations, il facilite en outre une planification harmonieuse de la pêche artisanale. Une mainmise abusive de l'Etat, une planification directe, aboutissent en effet le plus souvent à de graves difficultés. L'institution permet alors de créer et d'organiser les structures d'accueil qui sont nécessaires, en amont comme en aval, aux bateaux qui augmentent de taille et de prix et qui produisent pour le marché ou l'exterieur en général, et non plus pour la subsistance de leurs équipages et du village. Ces structures d'accueil intéressent tous les domaines de l'activité de pêche, aussi bien l'avitaillement, le crédit et le conseil, que la transformation et la commercialisation.

Structures d'accueil

Le credit — Les bateaux sont coûteux, fragiles et s'usent rapidement. Dans le cadre d'une économie fermée, au niveau de chaque village, leur financement est assuré tant bien que mal car fournisseurs et commerçants ne peuvent laisser la pêche péricliter: l'ensemble des affaires locales s'équilibre dans le cadre d'un circuit économique primaire et isolé. Dès que d'autres opportunités financières viennent s'offrir, ou plus généralement dès que l'on passe de l'économie de troc à l'économie de budgets et d'investissements, cet équilibre s'écroule: dès lors, le bateau n'est plus un outil que l'on achète avec l'aide éventuelle de personnes directement intéressées mais un investissement qu'il faut rentabiliser et amortir.

Cette rupture avec l'économie de troc est facilitée par la présence d'une structure de crédit. Les circuits classiques de financement ont en effet tendance à délaisser la pêche, dont la rentabilité immédiate est faible et dont les besoins financiers sont très particuliers. Outre l'avantage de pouvoir distribuer des aides d'Etat ou d'organisations internationales, la structure de crédit peut développer ses ressources propres. En effet, comme l'ont montré de nombreuses expériences, c'est plus par l'absence de moyens de collecte que par sa faiblesse apparente que l'épargne des pauvres reste improductive. Mais le drainage de cette épargne, particulièrement diffuse, sa transformation en investissements productifs, ne peuvent se faire que par le canal d'un établissement présentant les garanties et la spécialisation nécessaires. Il faudra, dans la pratique, une petite caisse de crédit épousant étroitement la vie du port mais possédant un minimum de structure bancaire.

Toutefois, le financement des bateaux de pêche exige une étroite coordination entre collecte de l'épargne et politique d'investissement, sous peine de voir les fonds reçus ne contribuer que médiocrement au développement de l'activité. Cette politique d'investissement ne peut se faire qu'à partir d'une connaissance individuelle des patrons et des équipages. La valeur des hommes est en effet le seul élément qui permette de juger de l'exploitation future, faute de meilleurs critères. La présence d'un conseil d'administration élu parmi les marins du port est un incontestable facteur de succès.

Le crédit s'accorde parfaitement au cadre d'une institution qui regroupe les caisses locales. Outre la priorité des problèmes de financement, c'est en effet l'organisation de crédit qui manifeste, dès l'origine, les plus grands besoins d'une structure nationale. Epousant étroitement la vie du port, et c'est là son rôle principal, la petite organisation de crédit ne peut rester isolée. Elle doit accéder aux avances que peut consentir l'Etat dans le cadre d'une politique d'aide et transformer à moyen et long terme les ressources d'épargne qu'elle collecte auprès de ses adhérents. Maniant des fonds relativement importants elle doit, en outre, faire l'objet d'une surveillance et de contrôles. Trop dispersée, elle risque aussi de rendre anarchique une politique d'investissement qui, plus que toute autre, nécessite patience, réflexion et concertation.

L'institution, au contraire, par sa forme intégrée, profite directement de l'augmentation de capacité d'épargne qui résulte de son action sur la productivité et les revenus d'investissement et pourra définir, dans les meilleures conditions, une politique d'investissement. Dès sa création juridique, elle est une structure cohérente; une trame qui organise les rapports entre échelons locaux, régionaux et nationaux. Aussi petites que soient, à l'origine, les organisations de base, souvent réduites à un guichet, le plan de développement a l'avantage d'être déjà tracé et, très vite, l'ensemble du système prendra de l'importance.

Les organisations amont et aval — La modernisation des bateaux et l'augmentation de leur taille ne peuvent se concevoir sans la création de "structures d'accueil" à vocation économique, capables de modifier corrélativement les conditions techniques et commerciales de la pêche locale. Ces nouvelles structures, constituées autour des services annexes à la pêche doivent préserver la rentabilité des bateaux et permettre une exploitation devenue plus complexe et plus technique.

Le plus souvent, les petites organisations de pêche doivent assurer leur croissance dans un climat dominé par la situation de crise, l'urgence des problèmes et la nécessité de lutter à la fois pour la maîtrise du milieu, des investissements et des marchés. Elles se trouvent dès le départ confrontées à des problèmes immédiats et urgents qui ont, le plus souvent, directement motivé leur création; il peut s'agir, soit de limiter des rentes de situation abusivement tirées par des commerçants ou des prestataires de la place, ce qui complique une lutte économique souvent très dure; soit de s'assurer un service nouveau destiné à soulager les équipages et les patrons de tâches à terre trop absorbantes; souvent aussi, les marins /pêcheurs doivent prendre la relève d'un entrepreneur défaillant, pour une activité indispensable au bon équilibre du port, comme la commercialisation, l'avitaillement et la réparation.

Les structures amont doivent permettre aux bateaux et à leurs équipages d'atteindre le niveau technique nécessaire à la modernisation. Elles doivent à la fois fournir le matériel, en assurer l'entretien et la réparation, en diffuser le mode d'utilisation et en limiter le coût. Elles ont donc à la fois un rôle d'appui logistique mais aussi de bureau d'étude, chargé en particulier de prévoir les problèmes à terme plus ou moins éloigné.

Les structures aval, en particulier celles qui assurent la commercialisation, jouent un rôle essentiel dans le développement de la pêche qui implique, avant tout, l'accès à des marchés, à des courants commerciaux extérieurs au village. Le système autarcique ne permet aucun accroissement des moyens de pêche, faute d'argent comme faute de débouchés. Les organisations à rôle commercial doivent assurer une pénétration des produits de pêche, et l'absence de marché est un facteur limitant très souvent constaté. Cette pénétration du produit, et la valorisation correspondante, peuvent se faire soit par les moyens classiques de l'économie de marché, par l'intermédiaire des criées et des halles à marée, soit dans le cadre de contrats tendant à concentrer l'offre jusqu'à assurer aux marins/ pêcheurs un quasi monopole de leurs produits ou toute autre organisation compatible avec l'organisation sociale du pays concerné par l'offre de développement. Ils peuvent ainsi en tirer toute la valeur.

Au niveau local, les petites organisations doivent en premier lieu assurer leur croissance, c'est-à-dire augmenter leur taille, concentrer les moyens dont elles disposent, améliorer leurs ressources propres. Dès le départ, elles doivent avoir une dimension suffisante. Tout leur avenir en dépend. De trop petite taille, elles ne peuvent assurer des coûts de production raisonnables, mais surtout elles ne peuvent s'assurer les services d'une équipe d'hommes compétents. A ce stade, le problème majeur réside, en effet, dans la présence d'une petite équipe de direction, hommes de terrain capables de mener à bien les premières luttes, de s'imposer dans l'esprit des marins /pêcheurs, dont ils doivent progressivement capter la confiance, et d'apporter aux affaires de la coopérative une gestion simple mais saine. C'est dans cette phase de lutte que se trempent les équipes qui provoqueront et suivront les phases ultérieures du développement. Trouver de tels hommes est la première obligation d'une organisation naissante. Très souvent, des solutions dictées par l'esprit d'économie ou la carence des candidats compromettent directement son développement ultérieur.

Les petites organisations doivent éviter de se lancer dans des investissements trop lourds, vers des activités encore mal connues, même si elles y sont poussées par les évènements. L'activité de service, nécessitant un capital réduit, est préférable: elle permet de former des équipes compétentes, de constituer une trésorerie, de consolider l'esprit de groupe au sein de l'organisation. Mais cette prudence n'est pas toujours possible et la croissance rapide est souvent, pour le port comme pour ses organisations, une véritable contrainte de survie.

Ces structures bénéficient d'un personnel déjà spécialisé qui peut conseiller et soutenir les marins/pêcheurs dans leurs efforts d'organisation. Elles jouent, dès l'origine, un rôle précieux de bureau d'étude. L'utilité des services qu'elles offrent leur confère en outre un poids qui leur permettra d'agir sur les conditions économiques et humaines du port.

Bien dirigée, l'organisation doit prouver la valeur de ses services et elle le fera d'autant plus facilement qu'étaient abusives les rentes de situation qu'elle a supprimées ou qu'est utile la fonction qu'elle est venue remplir. Mais la petite organisation de base risque de voir très vite plafonner son activité. Exerçant un métier très particulier, elle est, en pratique, isolée de toutes les formes d'activités économiques du port et du littoral. Limitée à quelques services simples, elle ne possède pas les moyens d'exercer des activités plus risquées, nécessitant une importante trésorerie, des compétences particulières ou des investissements importants. Dès lors apparaît la nécessité de concours extérieurs, de services au second degré destinés, non plus aux adhérents, mais à l'organisation elle-même. De tels services doivent lui permettre de rompre son isolement et ses cloisonnements et de recevoir une incitation économique. C'est seulement en y accédant qu'elle pourra en faire bénéficier les sociétaires.

Le développement fédératif

La petite organisation de pêche revêt, avant tout, un caractère local qui implique une meilleure efficacité, mais également un rapide plafonnement des activités. Tout comme la gestion d'un système bancaire, des activités comme l'industrie de la conserve ou du froid, le mareyage et l'approvisionnement de masse, souvent indispensables à l'équilibre et au développement des pêches, ne peuvent se concevoir à l'échelle de la petite organisations de base. C'est au niveau de regroupements fédératifs régionaux ou nationaux que se créent ces nouvelles fonctions, afin d'élaborer une véritable politique industrielle et commerciale et de concentrer, dans la pratique, la puissance économique et le pouvoir compensateur des marins/pêcheurs. C'est là un des principes directeurs du développement des petites organisations de pêche. Il aboutit à la création d'un édifice, disposant d'une puissance économique et industrielle propre, qui vient consolider ce qu'a de précaire l'exploitation des bateaux en mer.

En régime pseudo-libéral ou assimilable, le schéma du développement est le plus souvent fédératif: les petites organisations vont créer une ou plusieurs unions régionales destinées, soit à leur rendre des services communs (par exemple une centrale d'achat ou de commercialisation), soit à créer des services nouveaux qu'elles ne peuvent remplir individuellement (par exemple une usine de conserves, un entrepôt frigorifique ou une société d'assurances mutuelles). Tout comme au niveau local, les intégrations portent sur l'aval ou l'amont de la pêche, reprenant des entreprises existantes ou en créant de nouvelles. Ces intégrations renforcent la cohésion de l'économie régionale des pêches. Verticales, elles fournissent aux producteurs un meilleur contrôle du marché et une diminution des coûts. Horizontales, elles sont un facteur de puissance et de productivité souvent plus profitable que cette recherche systématique du "circuit court" qui obnubile les marins/pêcheurs. Mais ces investissements risquent souvent de se produire de façon désordonnée: les pêcheurs qui siègent aux conseils d'administration des unions régionales, ont souvent une vue schématique et déformée des problèmes industriels. D'autant plus que la logique de développement d'une industrie comme la conserve ou la surgélation peut être en contradiction avec les impératifs locaux de la pêche. Surmonter ce divorce entre production, transformation et consommation, qui est presque général dans l'économie des pêches, est un problème malaisé. Il explique les fréquentes incohérences de la politique industrielle menée par les marins/pêcheurs, toujours tentés par l'aventure et mal préparés aux embûches du marché et de la concurrence. Le succès de l'organisation régionale de crédit peut, paradoxalement, accentuer ces incohérences en rendant leur financement trop aisé. Aussi, au niveau régional comme au niveau local, est-il important de coordonner étroitement les politiques de ressource et d'investissement.

La difficulté que rencontre la région à définir une stratégie industrielle vient imposer une fédération au second degré; la création des unions nationales spécialisées qui intègrent, à un plus ou moindre degré, les entreprises régionales d'une même branche. Disposant de spécialistes expérimentés, elles peuvent leur apporter l'assistance souhaitable et contrôler la logique de leurs investissements. Ce complexe économique ne doit pas avoir le caractère hiérarchique que les Etats sont souvent tentés de lui donner dans un but de contrôle ou de mainmise. Il importe au contraire que l'initiative, l'information, le contrôle et même la contestation puissent circuler tout aussi bien par la voie montante que par la descendante. Dans la pratique, l'institution doit être un club d'hommes aux préoccupations différentes mais ayant un but commun. Les contacts doivent être les plus fréquents et cordiaux possibles, ce qui permet aux difficultés de se résoudre souvent d'elles-mêmes, entre "spécialistes" et "professionnels".

Aussi nécessaire que soit, dans la pratique, une structure souple décentralisée, il n'en demeure pas moins que les dirigeants régionaux et nationaux doivent supporter des responsabilités particulièrement lourdes. La base de tout l'édifice reste la pêche, activité fragile, entièrement fondée sur la compensation de petits risques et sur la résistance traditionnelle des petites exploitations familiales, dont le pouvoir de résignation est quasi illimité. Sur cette base, la concentration des investissements que réalise l'institution, soit sur des bateaux toujours plus importants et coûteux, soit sur des industries entièrement tributaires de la pêche, lui fait courir des risques énormes. Il est indispensable d'évaluer et de limiter ces risques. Les incertitudes de la biologie doivent pouvoir s'évaluer en termes économiques et financiers, faire l'objet d'un calcul économique au moins approché. Les révolutions alimentaires qu'apporte la technologie moderne doivent être suivies, d'autant plus que le poisson est rarement un aliment de base et que son avenir apparaît souvent comme incertain. L'évolution rapide du droit international de la mer impose de nombreuses contraintes qui doivent être considérées dans le cadre de toute politique d'investissement.

L'institution doit jouer un rôle de réflexion économique, d'initiative et d'animation de l'ensemble des organisations. Ces fonctions à caractère prospectif, cette réflexion économique, doivent être intégrées à la politique générale de l'institution dont elles peuvent paraître, en dernière analyse, comme une des raisons d'être majeure.

ANIMATION ET FORMATION

La création d'une petite organisation, tout comme son développement ultérieur, ne se fait qu'à la suite d'une maturation des esprits que favorise beaucoup le travail de groupe au niveau local. Cette forme de travail, à la pêche plus qu'ailleurs, est une méthode prodigieuse de décision. Plus qu'ailleurs, les problèmes sont d'approche difficile pour un spécialiste extérieur, même habitué au milieu maritime, alors que ceux qui les vivent quotidiennement y accèdent d'emblée.

Le lancement de nouvelles activités ne peut se faire le plus souvent qu'après un long travail d'animation mené par des spécialistes ou par la longue patience d'une équipe de dirigeants très convaincus, capables de gagner la confiance de leurs pairs. Des voyages en groupe de courte durée sont également à conseiller. Ils présentent l'avantage, à la fois de sortir les marins du cadre mental de leur bateau ou de leur port, et de leur montrer des réalisations dont l'intérêt doit les marquer. Toutefois, aussi importants que soient les problèmes d'animation, ils ne doivent pas concourir à créer des organisations trop petites, ce qui est un risque fréquent. Le groupe de base peut être une petite "coopérative d'idées" dont la vitalité et l'initiative seront précieuses. Mais l'organisation de pêche proprement dite, celle qui devra prendre des responsabilités économiques, engager du personnel, justifier le coût de ses services, doit atteindre une taille minimale. Les "coopératives d'idées," aussi souhaitables qu'elles soient, doivent rester telles et assurer un premier regroupement pour aboutir à l'organisation de pêche proprement dite. C'est là une des difficultés majeures des politiques nationales que de définir ce juste équilibre entre organisation "spontanée" et structure économique.

La formation des hommes doit précéder et renforcer toutes les phases du développement des organisations de pêche. Le passage d'une mentalité traditionnelle à un esprit de progrès nécessite une irrigation intellectuelle constante. Dans le domaine technique, les éléments du développement peuvent être apportés par des programmes de vulgarisation, mais seule la formation intégrée peut préparer les hommes à une idée nouvelle de leur métier, et renforcer leur cohésion sociale.

Le pouvoir dans les petites organisations pose un difficile problème d'équilibre entre les exigences de la participation effective et la nécessité d'actions parfois contraignantes. La présence d'un "tiers pouvoir", au niveau de l'institution, permet de maintenir cet équilibre et de préserver l'intérêt général.

RÔLE SOCIAL

Le développement fédératif n'enlève rien de sa vitalité à la petite organisation de pêche. Bien au contraire, les unions régionales et nationales ont renforcé sa position locale, lui apportant de nouveaux moyens et de nouvelles perspectives. Très rapidement, elle peut envisager d'étendre la gamme des services qu'elle rend à ses adhérents. Initialement limités à quelques prestations directement liées à la pêche, ces services vont se dématérialiser progressivement, faire parvenir la pêche, à des degrés supérieurs d'organisation, et finir par englober pratiquement tous les aspects de la vie du port. En un premier temps donc, les prestations apportées concernent très directement l'exploitation. Ce sont l'avitaillement, l'entretien, la mise au marché, éventuellement la tenue des comptes. En limitant les coûts, en soulageant patrons et équipages de tâches absorbantes, elles contribuent au maintien de la pêche. Ces prestations de base assurées, les petites organisations peuvent développer des services plus affinés, moins liés aux opérations matérielles et exigeant un personnel plus compétent. Peuvent entrer dans cette catégorie toutes les mesures visant à organiser l'economie locale des pêches: les fonds de péréquation ou de soutien jouent un rôle des plus précieux dans la défense des prix et des revenus. Alimentés par une cotisation modique, le plus souvent une retenue sur les ventes, ils bénéficient du support des unions et de leur appareil industriel et commercial; les caisses d'assurance viennent effacer les risques de toutes sortes, qu'ils concernent les bateaux, les hommes ou l'exploitation (caisses d'intempérie par exemple); les services de conseil se développent rapidement: conseils techniques, conseils à la gestion puis conseils qui, très vite, s'étendent à tous les aspects de la vie des marins/pêcheurs, et prennent l'allure d'une véritable assistance.

Les services ainsi rendus peuvent déborder plus largement le cadre professionnel. Par exemple, les absences prolongées, la fameuse indisponibilité des marins/pêcheurs, leur crée de grandes difficultés à résoudre leurs problèmes personnels et familiaux, et ils ont le plus grand besoin de "correspondants" à terre capables de les assister en permanence.

La petite organisation de pêche se trouve très vite confrontée à des problèmes de fond. Aussi parfait que soit l'appareil économique tissé autour des bateaux, aussi poussés et utiles que soient les services qu'elle a créés et développés à terre, elle doit se préoccuper des conditions de vie à la mer. C'est en effet à bord que les hommes rencontrent leurs difficultés majeures. Le bateau est le plus souvent l'unité d'exploitation irréductible, indépendant de la terre comme du reste de la flottille, jaloux de son autonomie. C'est une frontière technique et morale pratiquement infranchissable. Patrons et équipages vivent dans un esprit de compétition effréné, qui se traduit par le fameux "secret de pêche." La vie à bord est généralement épuisante et inconfortable, sans grande spécialisation des tâches, ni économie de main-d'oeuvre. Or, l'augmentation du prix des bateaux, le coût d'appareils de plus en plus complexes, imposent une course constante à la productivité qui, pour un bateau isolé, ne peut s'obtenir qu'en réduisant le temps passé à terre et en allongeant des horaires de travail à la mer, étant donné que la petite pêche n'est pratiquement pas mécanisable. En fait, les équipages travaillent aux limites de leur résistance physique, sans que les résultats progressent sensiblement.

On assiste dans la pratique à un gaspillage considérable du travail et des capitaux. De plus, l'esprit de concurrence anarchique est de plus en plus incompatible avec l'exploitation rationnelle d'un stock limité de ressources biologiques. Regrouper et coordonner l'effort de pêche doit être un souci majeur de l'organisation de base. Mais elle ne peut y parvenir que par une modification en profondeur des habitudes, des structures et des mentalités. C'est avant tout une question de formation d'initiative et d'esprit expérimental. L'organisation de pêche peut alors confirmer son rôle social en organisant le travail à bord, les rotations des bateaux et des équipages, en développant la pêche groupée et même la pêche scientifique en s'appuyant sur le concours de biologistes et en profitant des techniques de repeuplement ou d'élevage. Cette voie est pratiquement illimitée; elle permet d'accroître les loisirs, d'accorder des congés payés et de garantir des revenus.

Cambios y Evolución de las Pesquerías en al Atlántico Centro-Oriental[1]

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Este trabajo se ocupa de la pesca en aguas marinas frente a las costas del Africa occidental, entre el estrecho de Gibraltar y Mauritania, zona que se caracteriza por la relativa estrechez de su plataforma continental, la presencia de la corriente de las Canarias y la intensidad de los afloramientos, que da lugar a una producción primaria elevadísima y una notable abundancia de fauna bentónica.

El autor estudia las principales pesquerías (de sardina, machuelo y alacha, merluza, espáridos, cefalópodos y crustáceos demersales) y analiza su evolución, la composición por especies, los caladeros y estaciones de pesca, las características biológicas de las poblaciones explotadas y los efectos de la pesca.

Se analizan también los criterios que han de tenerse en cuenta a la hora de planificar la inspección y regulación de estas pesquerías.

This paper deals with the marine fisheries off the West African coast, between the Straits of Gibraltar and Mauritania, an area which is characterized by its relatively narrow continental shelf, the presence of the Canary Current, and intensive upwelling resulting in very high primary production and rich bottom fauna.

The main fisheries (for sardines, sardinellas, hakes, sparids, cephalopods, and demersal crustaceans) are analyzed with regard to their evolution, species composition, fishing areas and seasons, the biological characteristics of the exploited stocks, and the effect of fishing on them.

The criteria to be considered when planning the control and regulation of these fisheries are also analysed.

Le présente document traite des pêcheries maritimes opérant au large des côtes de l'Afrique de l'Ouest, entre le détroit de Gibraltar et la Mauritanie. Cetee zone est caractérisée par la relative étroitesse du plateau continental, par la présence du courant des Canaries et par l'intensité de l'upwelling, facteurs qui expliquent l'importance de la production primaire et la richesse de la faune benthique.

L'auteur analyse les principales pêcheries (sardines, sardinelles, merlus, sparidés, céphalopodes et crustacés démersaux) sous divers aspects: évolution, composition par espèces, zaones et époques de pêche, caractéristiques biologiques des stocks exploités et incidences de la pêche sur ces stocks.

Sont également examinés les critères à appliquer dans la planification du contrôle et de la réglementation de ces pêcheries.

La costa y la plataforma africana en la vertiente atlántica puede considerarse dividida en tres secciones, cada una de las cuales presenta características particulares. En primer lugar se señala la zona comprendida entre el Estrecho de Gibraltar y la región de Cabo Verde; la segunda corresponde a la zona situada desde Angola hasta el Cabo de Bueno Esperanza y finalmente, la zona central está situada en el Golfo de Guinea. Las dos primeras zonas mencionadas se caracterizan por estar situadas en zonas de elevadísima productividad primaria mientras la tercera, por su misma estabilidad, se encuentra en situación mucho menos privilegiada. Aquí se tratará ùnicamente de la primera de las áreas mencionadas, y más concretamente, el área comprendida entre el estrecho de Gibraltar y Mauritania. La plataforma en general no se caracteriza por su gran amplitud, que es màxima a la altura de la península de Río de Oro, donde alcanza unas 75 millas de amplitud entre la costa y la isobata de los 100 m. A esta profundidad normalmente se inicia el talud continental. Tanto en la costa de Marruecos como en la de Mauritania la plataforma es estrecha y muy abrupta en la parte situada al sur de Cabo Blanco.

Existen en esta zona dos circunstancias de gran importancia para el conocimiento de la estructura pesquera y de sus posibilidades: la primera es la existencia de la corriente de Canarias y la segunda, los grandes afloramientos que tienen lugar en la zona de Ifni y de Cabo Blanco. La potencia de estos afloramientos es tan considerable que pueden ser considerados como entre los más potentes del mundo dando lugar a elevadas concentraciones de nutrientes en superficie como se desprende de las expediciones oceanográficas llevadas a cabo más recientemente.

Esta grande y duradera aportación de nutrientes a la

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[1] Preparado para la "Conferencia Técnica sobre Ordenacion y Desarrollos Pesqueros," de la Organizacion de las Naciones Unidas para la Agricultura y la Alimentación, celebrada en Vancouver, Colombia Británica, Canadá, del 13 al 23 de febrero de 1973.

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superficie determina el constante enriquecimiento y abundancia de plancton que sostiene una densa población de peces pelágicos pertenecientes a distintas especies cuya explotación es de importancia muy considerable.

Con independencia de estos fenómenos ligados a la dinámica terrestre, en la zona comentada existen importantes áreas de enriquecimiento debidas a la influencia de los vientos cuya componente del NE es la más constante y de la corriente de Canarias, especialmente al rozar ésta con algunos de los salientes litorales. Estas zonas de afloramiento determinan la existencia, entre los grandes afloramientos citados, de una especie de continuidad que se manifiesta especialmente por la riqueza de los fondos, ricos en diversas especies de espáridos, merluzas y cefalópodos, entre los grupos más importantes.

Tipos de pesquerías

Se trata, en primer lugar, de separar cuidadosamente los tipos de pesca existentes en esta zona; debemos señalar que la zona del gran afloramiento norteño se caracteriza por la existencia de enormes concentraciones de sardina, circunstancia que permite a Marruecos situarse en primera línea en la explotación pesquera mundial. Por el contrario en la zona de Cabo Blanco ha desaparecido la sardina y en su lugar aparece la alacha de características predadores y ecológicas parecidas, especie que se sostiene gracias a la enorme producción marina de esta zona.

PESQUERIAS PELAGICAS

La sardina marroquí se extiende, en general, por toda la costa desde el norte de Villa Cisneros hasta Gibraltar, pero su máxima concentración se encuentra al sur de Marruecos a la altura del paralelo 32. Las circunstancias de alta producción marina y la mayor amplitud de la plataforma en esta zona, permiten la existencia muy firme de un gran stock de esta especie. La explotación está centrada especialmente en Safí y Agadir que son los principales puertos de pesca. Los países explotadores son principalmente Marruecos y en segundo lugar, pescadores del sur de la península ibérica. En realidad las pesquerías de peces pelágicos, predominantemente sardineras, no se encuentran aisladas sino que colindan con la pesca de extensos cardúmenes de anchoa, ubicados especialmente en la parte norte de la costa marroquí y de alacha que se acerca en bastante cantidad al sur de Villa Cisneros. Las especiales características biológicas de la sardina hacen que no pase hacia el sur más allá del paralelo 25°N a causa de la temperatura demasiado elevada de las aguas marinas. Por lo que atañe a la relación existente entre la sardina y la anchoa es importante señalar la posibilidad de sustituciones en los cardùmenes de estas especies, fenómenó observado en otras áreas con las mismas especies y también para otras especies diferentes aunque tengan características semejantes. Sin embargo en el momento presente la sardina parece acantonada a la zona de mayor producción marina, mientras la anchoa, menos abundante, se sitúa más al norte que aquélla.

Las características biológicas de la sardina marroquí estudiadas, (Furnestin, Andreu y otros) muestran la existencia de diferencias que afectan tanto al número de vértebras (±51) como al de branquispinas (±80) así como a las características del crecimiento, de tal forma que dicha sardina debe ser considerada como una raza localizada en dicha área con características estrechamente relacionadas con el ambiente que le es propio, las cuales sin duda es preciso tener en cuenta cuando se programa el control de la explotación de dicha población de peces.

Las pesquerías de alacha o sardinela se situan en la zona de Cabo Blanco lugar donde se encuentran las mayores concentraciones de estos animales. En realidad no existe una población constituida por una sola especie sino que conviven varias de ellas, entre las que hay que destacar *Sardinella aurita*, *Sardinella eba* y *Sardinella maderensis*, ésta última es la menos abundante de las tres. Alcanzan mayor tamaño que la sardina, pero al igual que aquélla, se alimentan de plancton, y debido a la enorme importancia de la producción de esta zona la densidad de estos peces es muy alta. La manera de comportarse de estas especies está menos conocida que la de la sardina por lo que serían de desear intensos estudios sobre las mismas. Se supone que verifican migraciones de norte a sur pero con independencia de los períodos de agregación y dispersión tan frecuentes en las especies de este grupo y de gran importancia para una adecuada explotación de estos bancos de peces. Las sardinelas pasan por períodos de vida en aguas más profundas en las que parece entran a constituir parte importante de la llamada capa difusora profunda. En tal situación son dificilmente capturables, al menos por medio de los habituales artes de cerco. La enorme producción biológica propia de la zona de Cabo Blanco, es la que mantiene la densísima masa de estas especies en estas aguas. Es interesante conocer con más detalle que el actual, los ritmos y oscilaciones en la zona de mayor producción para correlacionarlos con las variaciones en la producción y movimientos de las alachas.

La explotación de estas especies destinadas en el momento actual en gran parte a la conversión en subproductos, se realiza principalmente mediante grandes buques-factoría que destacan flotillas que se dedican a la pesca de los cardúmenes de las mismas. Se utiliza normalmente el arte de cerco, pero algunas flotillas utilizan también artes de arrastre pelágicos con excelentes resultados. Otro aspecto que es interesante señalar aquí es la interacción posible y seguramente existente entre las distintas especies de sardinela. Se trata de cuestiones que deben ser rápidamente experimentadas si se quiere llegar a un auténtico control y a un planteamiento adecuado en la explotación de estas especies. Por lo que atañe a los contactos con especies parecidas hay que señalar que las sardinelas se encuentran en toda la costa norte-africana, sin embargo no son frecuentes en concentraciones tan importantes como sucede en el área que estamos comentando. Al contrario que la sardina, que como se ha indicado, no traspasa hacia el sur del paralelo 25°N la alacha se extiende más, por lo que la mezcla de ambos géneros de clupeidos sólo se da en la zona norte. En el sur los contactos son con especies que no llegan a formar concentraciones importantes.

Características biológicas — *Sardinella aurita* y *S. maderensis* son abundantes en la zona. La primera se caracteriza por tener de 100 a 120 branquispinas en la parte inferior del primer arco branquial. Se conocen una serie de razas locales características de cada zona. Se la encuentra cerca de la costa y en alta mar. El crecimiento es rápido y al año de vida, el nacimiento tiene lugar en verano cuando el aqua tiene temperatura elevada, alcanza 16 cm y es apta para la reproducción, circunstancia que favorece grandemente la recuperación de la especie. Cuando las aguas se enfrían en la costa se retira a alta mar. Su alimentación está constituida por plancton de bastante tamaño a causa de la amplitud de la criba de las branquispinas. Alcanza hasta 30 cm de longitud total. La segunda de las especies es de cuerpo más alto y comprimido. El número de branquispinas varía más ampliamente, entre 90 y 166 cm quizás en relación con la edad y quizás con una subdivision de especies.

PESQUERIAS BENTONICAS

Las pesquerías bentónicas tienen una importancia capital en el área que estamos estudiando y han experimentado una tremenda evolución como resultado de la acción de la pesca. Las pescas tradicionales en estas costas estuvieron constituidas por las merluzas en el talud y las zonas más profundas de la plataforma continental en todo el litoral señalado; en este sentido se indican actualmente en la parte sur la fosa de Cayar, cercanías de Cabo Tímiris y Cabo Blanco entre las más productivas. Las merluzas citadas en el área pertenecen a dos especies distintas aunque sus comportamientos son parecidos; se trata de *Merluccius merluccius*, la merluza europea, de carne blanca y la merluza negra o del Senegal *M. senegalensis*. Podría aceptarse como zona de transición entre ambas especies la de Cabo Blanco, si bien la transgresión entre ellas parece ser considerablemente amplia. Los tamaños medios obtenidos actualmente tanto de la una como de la otra especie, son bastante reducidos y se impone un serio esfuerzo para reducir la intensidad de pesca.

Una segunda e importante pesquería la constituyen los espáridos. En realidad la variedad de tales especies es considerable destacando *Dentex macrophthalmus*, *D. dentex*, *D. canariensis*, *Spondioliosoma cantharus y* especialmente *Pagellus belloti y P. acarne* entre otras de las especies que tienen interés en esta zona. Desde el punto de vista faunístico las especies pertenecientes al grupo de los espáridos constituyen un importante grupo, con gran número de especies representadas en la zona. En las aguas más profundas se encuentra mayor variedad, tamaños mayores, aunque siempre en cantidad ciertamente reducida; ello se debe en gran parte a la intensa pesca a que han sido sometidos. Por el contrario en aguas menos profundas se encuentra menos variedad y tamaños más pequeños, pero, en ocasiones, gran cantidad de ejemplares.

CEFALOPÓDOS

La tercera de las especies importantes en las pescas de fondo son sin duda los cefalópodos. Tales especies han evolucionado en su aspecto pesquero de modo especial en los últimos doce años y parece que su abundancia corre pareja con la disminución de los espáridos. Se conocen varias áreas en las que los cefalópodos son abundantes; destaca como la más importante la situada entre los paralelos 23°N y 25°N, en fondos más bien cercanos a la costa y siempre muy poco profundos. Se explotan otras áreas dispersas; una al norte de Cabo Blanco y en la actualidad parece que se pone en explotación otra importante zona situada en las cercanías de Dakar.

En realidad la explotación fundamental de los cefalópodos se basa en tres especies: los pulpos (*Octopus vulgaris*), la sepia (*Sepia officinalis* var. *hierredda*) y el calamar fundamentalmente constituido por *Loligo vulgaris*. A estas especies hay que añadir cierta cantidad de *Loligo forbesi* especialmente en aguas alejadas de la costa y diferentes especies del género *Sepia* también propias de aguas más profundas; éstas últimas se caracterizan por su menor tamaño y también por la menor calidad de su carne; tienen escasa importancia comercial.

De las experiencias llevadas a cabo por diferentes autores se deduce que la zona de puesta del pulpo, especialmente por lo que se refiere a la zona norte (23–25°N) se sitúa en la parte más superior y siempre cerca de la costa, aprovechando posibles refugios naturales. En general hay que señalar que lejos de la costa, a cierta profundidad, entre 60 y 80 m, se encuentran cierta cantidad de pulpos de gran talla pero en número ciertamente escaso. Las sepias se encuentran prácticamente en la misma área que los pulpos; muestran una acusada disminucion en las capturas, que se manfiesta en la casi desaparición en dichas capturas de la segunda y tercera generación. El calamar también ha disminuido mucho, pero sus costumbres semipelágicas que le permiten separarse del fondo durante largas temporadas del año, le salvaguarda de una pesca demasiado intensa sólo efectiva cuando se acerca al fondo (entrada del calamar). Su área de dispersión es más amplia y está más en consonancia con los movimientos de que es capaz, por lo que parece superior a la de las otras especies. Esta misma circunstancia da como resultado una mayor variabilidad en la composición de las capturas anuales, de tal forma que es difícil separar la evolución debida a la pesca de la evolución propia, debida a su mismo dinamismo.

OTRAS ESPECIES

Las pesquerías demersales en esta importante área pesquera están complementadas por la existencia de otras especies; entre ellas se destacan las landostas *Palinurus regius*, *Palinurus mauritanicus* y *P. vulgaris*. los peneidos *Aristeus antennatus*, *Aristeomorpha foliacea*, *Plesiopenaeus edwarsianus* y *Penaeus duorarum* en la parte norte y las corvinas, *Corvina* s*P*., entre las de mayor interés. La corvina se encuentra formando pequeños grupos cerca de la costa y es capturada especialmente cuando verifica movimientos para entrar en las bahías resguardadas, como la de Villa Cisneros y especialmente la del Galgo. Las pesquerías de esta especie han decrecido considerablemente en los tiempos actuales. Las langostas pertenecen a diferentes especies y se encuentran aún con cierta abundancia en las cercanías de Cabo Blanco, en su parte norte. Son intensamente pescadas utilizando las nasas, y son remitidas directamente a los mercados europeos vía aérea. Las pesquerías de peneidos son de varias clases y en general se trata de especies que viven en el mismo talud continental. En la costa marroquí se encuentran diferentes especies *Aristeus antennatus* y *Aristeomorpha foliacea*. Por el contrario en la parte sur parece ser más abundante *Plesiopenaeus edwarsianus*. La producción de estas especies no puede competir con las pesquerías de camarón de aguas más someras, pero, sin embargo, admiten una mayor capacidad de regulación.

Explotación

Seguramente lo más interesante en estas diferentes pesquerías demersales lo constituye el diferente comportamiento de estos animales frente a las características del medio, frente a su explotación y el tipo de crecimiento que las caracteriza. En general, tanto las merluzas como los espáridos, aunque principalmente éstos últimos, se caracterizan por un crecimiento relativamente lento y una capacidad de recuperación escasa; esto significa que frente a una pesca intensa se adaptan difícilmente a tal circunstancia. Por otra parte son muy vulnerables debido a la posibilidad de capturarlos en cualquier época del año, e incluso en la edad juvenil. En estas circunstancias una pesquería corre peligro muy serio de su extinción, al menos desde el punto de vista económico.

Por el contrario existen otras pesquerías como las que aprovechan los crustáceos profundos que son capaces de un gran poder de renovación y por su especial y eficaz metabolismo son capaces de mantener un crecimiento intenso y una elevada capacidad de reproducción, de tal forma que, en especial en el caso de *Aristeus antennatus* son capaces de multiplicarse cuando tan solo tienen un año de vida. Por otra parte los tamaños más solicitados por los intereses de la pesca no resultan perjudiciales para el equilibrio biológico de la población, objeto de la explotación. Los stocks juveniles no reclutados de estas especies se encuentran completamente salvaguardados de la acción de la pesca industrial por sus especiales condiciones ecológicas. En tales casos si bien es cierto que el stock explotado puede mermarse considerablemente, no puede ser rebajado más allá de las condiciones mínimas que representan su crecimiento y el reclutamiento anual.

Cuando se trata de los cefalópodos y en particular del pulpo, sin duda la especie de mayor interés entre las varias explotadas, la experiencia indica que es capaz de un intenso crecimiento, que le permite alcanzar tallas considerables en un tiempo mínimo. Este aspecto se nota muy directamente cuando se trazan las curvas de distribución de tallas, que al contrario de lo que sucede en el caso del calamar y la sepia, se distribuyen formando una única curva de campana, característica de la existencia de una única generación o grupo. Esta circunstancia, junto con su elevado poder reproductor, implica, lo mismo que en otros stocks parecidos, la existencia de un gran poder de regulación y al mismo tiempo la posibilidad de grandes oscilaciones en la abundancia de los stocks muy directamente influenciados por cada generación anual. En tal circunstancia tan sólo grandes series de datos estadísticos que permitan eliminar oscilaciones debidas a circunstancias ajenas a la pesca, servirán para tener un criterio adecuado de la marcha de la pesquería. En estos casos, tanto en el anteriormente citado de los crustáceos de fondo como en el de los pulpos, ocurre algo parecido a las especies de régimen directamente planctófago, como la sardina y las alachas. En todos ellos es más interesante el control de la actividad desde el punto de vista de la economía de las embarcaciones que desde el punto de la acción directa sobre los cardúmenes ya que éstos pueden reducirse de tal forma que el rendimiento por unidad de acción de pesca resulte reducido y sin rentabilidad.

Entre los espáridos y los cefalópodos se ha establecido no obstante una curiosa competición favorecida por la misma acción pesquera. Las zonas comprendidas entre la costa y la isobata de unos 100 m y en especial en la costa del Sahara fueron tradicionalmente ricas en pesca de espáridos de diferentes especies; la explotación intensiva de estas especies cuyas características son, como se ha indicado, precisamente las opuestas a las señaladas para el caso de los cefalópodos y las gambas de profundidad, es decir, crecimiento no muy intenso y exposición casi total a los artes de pesca, ha dado como consecuencia la continua explotación y disminución de los stocks de los animales. Correlativamente, los celfaópodos fueron aumentando y en especial la pesca del pulpo el cual, como hemos indicado, está afectado de la mayor intensidad de crecimiento; las otras especies no han progresado de la misma forma. Por una parte hay que tener en cuenta que los pulpos constituyen uno de los alimentos más preciados por parte de los espáridos y en segundo lugar que la disminución de la competencia espacial es también de gran interés en el desarrollo de una población de peces, especialmente en una zona donde el potencial de creación de alimentos idóneo — moluscos, pequeños crustáceos, etc — es extraordinario.

Desde el año 1961 acuciados además por el alto interés económico de la nueva pesquería debido a los altos precios alcanzados por los cefalópodos que hasta aquel momento no tenían apenas interés en el mercado mundial (quizás en esto haya jugado un importante papel la entrada de pescadores japoneses con la iniciación de nuevos mercados y utilización de los productos) se intensifica la prospección y se organiza la explotación de estos animales. A partir de esta fecha la explotación se incrementa para alcanzar valores considerables en 1971 en el que un solo barco-factoría dotado de una flotilla de operaciones de unas 50 unidades de arrastreros de tipo medio, elaboraba diariamente un centenar de toneladas de la cuales la mayor parte deben ser consideradas como pulpos. Hay que tener presente que paralelamente a estas actividades están las de otras flotas de las cuales solamente la japonesa y en esta misma zona—banco sahriano—captura la misma cantidad que los pesqueros españoles, representando entre ambos la mayor potencia de explotación en la zona para estas especies.

Cabría pensar si al igual que sucede en otras explotaciones pesqueras la variación en la abundancia o aparente sustitución de unas especies por otras fuera debida a la existencia de fenómenos naturales; ejemplos de este tipo son conocidos de la literatura mundial. Sin embargo, las experiencias realizadas en las campañas oceanográficas más recientemente desarrolladas en la zona y en especial las "Sahara I" y "Atlor I" demuestran que en la misma zona donde se pescan abundantemente los cefalópodos no han dejado de existir considerables cantidades de espáridos entre los que abunda especialmente *Pagellus acarne* como una de las especies de mayor importancia. Lo que sucede es que el tamaño de los ejemplares es sumamente reducido especialmente en las zonas poco profundas, resultado, sin duda, de la intensa explotación a que fueron sometidos y actualmente, a la competencia a que están expuestos por parte de los cefalópodos, en la actualidad ocupantes preferentes del área en cuestión. En tal caso queda muy patente la importancia que tiene el adecuado control de la actividad pesquera que es capaz de desencadenar un cambio tan importante como el indicado, que si bien en el caso concreto citado no ha sido perjudicial pues a un tipo de explotación le ha suplantado otro de gran interés económico, sin embargo lo más probable sería su sustitución por especies de gran poder de crecimiento y adaptación pero carentes de interés para su utilización por parte de la industria de la pesca.

El examen de la totalidad del área demuestra que los espáridos siguen estando ampliamente distribuidos ocupándola totalmente tal como era tradicional, de tal forma que en la costa se encuentran los ejemplares jóvenes y, más alejados en aguas más profundas, un menor número de ejemplares viejos y de gran talla. Algo parecido ocurre con el pulpo que se encuentra igualmente diseminado. Ahora bien, la pesca intensa en la zona típicamente objeto de la explotación de los cefalópodos, impide el adecuado desarrollo de los stocks encargados de nutrir los bancos de espáridos de alta mar y agota prácticamente a los cefalópodos los cuales, por estar mejor adaptados y tener más rápido crecimiento y así mismo un poder de reproducción más elevado, son capaces de mantenerse en condiciones relativamente óptimas en la zona costera objeto de explotación. En concordancia con lo indicado hay que señalar que las mayores explotaciones actuales de espáridos llevadas a cabo por las flotas japonesas especialmente de *Pagellus belloti*, se efectúan al sur de esta zona, en las cercanías de Senegal, donde las explotaciones de cefalópodos son muy inferiores y, en todo caso, según se ha indicado más arriba, relativamente recientes.

Resumiendo, en este caso se trata de la acción de la pesca que favoreciendo un lado de la competencia biológica desplaza el equilibrio sistemáticamente hacia el mismo. Actualmente no se está en condiciones de conocer si un adecuado control sería, en el caso de que ello fuera interesante, capaz de retornar la explotación al primitivo auge de los espáridos.

En zonas especialmente situadas cerca de la costa y en algunas áreas de arrastre de plataforma es abundante la langosta. Como consecuencia de su disponibilidad para la pesca y de su lento crecimiento, las langostas han mostrado oscilaciones muy acusadas y en los momentos actuales las especies explotadas son distintamente consideradas por las diferentes flotas que actúan en la explotación, especialmente en lo que atañe a las cercanías de Cabo Blanco. Las flotas francesas que pescan en la zona muestran una acusada disminución, mientras, por el contrario, las flotillas españolas son, al parecer, más rentables en los momentos actuales; sería interesante conocer el resultado de la comparación de los esfuerzos y métodos empleados por cada una de las distintas flotas.

En realidad, una gran parte de la pesca de la zona comprendida en el área del CECAF se nutre de la pesca de peces semipelágicos del grupo de los pequeños escómbridos y de los carángidos; se trata especialmente de la caballa (*Scomber japonicus*), el chicharro (*Trachurus trachurus*) y el jurel (*Decapterus ronchus*) entre otras, a las que pueden acompañar especies de mayor o menor importancia según las épocas. Sólo hay que tener en cuenta que de la totalidad de la pesca consignada para 1968, ligeramente superior a las 2,000,000 de toneladus métricas, más de una cuarta parte fue capturada por flotillas cuya pesca más importante se centra en la explotación de estas especies. A ello hay que sumar los esfuerzos de otras flotas también muy interesadas en la captura de estos animales.

Son peces que constituyen grandes bancos errantes dentro de pequeñas áreas y que son capaces de interesantes migraciones verticales especialmente durante ciertos períodos del año. Es frecuente que pasen una parte del otoño, mientras se preparan para la próxima freza, en aguas cercanas al fondo y la primera parte del año en aguas superficiales. En tales circunstancias los artes de arrastre de gran abertura vertical, los de cerco y aun los arrastres pelágicos de superficie son los más idóneos para su captura. Su crecimiento y poder de reproducción son altos pero así mismo por su comportamiento se encuentran situados más cerca de los peces pelágicos, y especialmente en lo que se refiere a su capacidad de recuperarse de la presión de la pesca. Sin embargo se sabe de algunas especies, por ejemplo la caballa común (*Scomber scombrus*), que experimentan enormes fluctuaciones a lo largo de los años, seguramente influenciadas por las características del ambiente. Su régimen de alimentación principalmente predador y carnívoro es importante en el período juvenil; entonces actúan directamente sobre el zooplancton beneficiándose de la alta capacidad de producción. de la zona. En el estado adulto la capacidad para ingerir grandes cantidades de elementos constituyentes de la capa difusora profunda permite a estos voraces animales disponer de gran cantidad de alimento muy rico en energía. Experiencias efectuadas con el chicharro (*Trachurus trachurus*) demuestran la gran cantidad de eufausiáceos de alto poder energético, que son capturados por los cardúmenes de estos peces. Solamente estas circunstancias explican y mantienen la densidad de estos cardúmenes y la posibilidad de que soporten una tan intensa explotación.

Organización de las pesquerías

Es importante en toda pesquería la acción inmediata que la pesca tiene sobre la estructura de los cardómenes. En el caso de tratarse de pesquerías de animales de superficie y en especial los emigrantes, es posible que el estado de agregación, imprescindible si se quiere lograr éxito en la explotación, dependa, en gran parte, de la acción ambiental: importancia de los agentes físicos y químicos, concentraciones de plancton, etc; pero en el caso de los peces de fondo se demuestra de gran interés para la determinación del estado mínimo de agregación la acción de la propia pesca. Experiencias efectuadas en los bancos de merluza sudafricana y en más pequeñas explotaciones en los fondos de pesca mediterráneos demuestran la importancia de este aspecto. En realidad la explotación de los grandes bancos por un elevado número de unidades pesqueras se caracteriza por la constante rotación en la ubicación de las flotillas de pesca. Las pequeñas áreas donde se detectan ciertas concentraciones de peces, en este caso de cefalópodos, son intensamente explotadas por la mayor concentración de barcos; el resultado es un agotamiento rápido de la pequeña agregación y la explotación pasa un período breve, generalmente de uno o dos días, en busca de nuevas agregaciones, que en cuanto son detectadas concentran rápidamente las flotillas que acaban por agotar el nuevo acúmulo. Siguiendo cuidadosamente el movimiento de estas flotillas durante largos períodos de tiempo, se observa que se van repitiendo los lugares comunes, permaneciendo durante los períodos de explotación en cada punto concreto un lapso de tiempo que varía alrededor de los 5–6 días, en general dependiendo de la concentración real momentánea y también de la intensidad del esfuerzo de pesca que se ejecuta. La disminución en cada situación no es por tanto efecto de una disminución real de la población explotada sino simplemente de la disminución de la agregación existente, por efecto de la misma acción dispersante de la pesca. Este es un aspecto al que se ha prestado escaso interés y consideramos que tiene importancia máxima en el control y en la explotación real de una pesquería. En realidad se precisan técnicas más exactas que las empleadas actualmente en el examen de la pesquerías para poder determinar este parámetro y aplicarlo a la obtención del máximo rendimiento y mínimo deterioro.

Las pesquerías capaces de mantener un alto nivel de explotación, deben sin duda estar dotadas de una alta capacidad de renovación la cual viene condicionada por las características de su biología: alta tasa de crecimiento y elevado poder de reproducción; por otra parte son condiciones idóneas aquéllas que permiten que los stocks juveniles estén automáticamente protegidos de la acción de la pesca. En el caso de las gambas de profundidad, de los pulpos, etc., y también de las pesquerías pelágicas o semipelágicas, se encuentran casi todas estas circunstancias menos las que se refieren a la protección de los cardúmenes juveniles, los cuales, solamente en el caso de las gambas, se encuentran habitualmente protegidos por el estado en que viven las propias larvas.

En estos casos el conocimiento de estos parámetros es condición indispensable si se quiere progresar en el adecuado planteamiento de la explotación de estos recursos. Cuando la explotación es excesiva los stocks se reducen pero sólo hasta tal punto que agota cada año la propia generación. En tales circunstancias, siendo imposible explotar la generación no reclutada por estar fuera del alcance de la pesca, ésta se mantiene a un nivel excesivamente bajo pero estacionario, con ligeras oscilaciones, fruto tan sólo de las influencias ambientales o de los ciclos de producción propios de la especie. El rendimiento sigue disminuyendo por unidad de captura al aumentar el número de éstas sin que de ello se siga que el stock disminuya de forma real. La competencia entre barcos se hace cada vez más aguda y en tal caso una disminución de la luz de las mallas no representa ninguna ventaja para los pescadores pues se supone que se agota la total generación mientras que un aumento de la malla, en lo que significa de disminución del esfuerzo, repercute mucho en la captura total por barco, medida difícilmente practicable en una situación como la descrita. Estas situaciones se dan de hecho en numerosos casos y en la costa africana centro-occidental se da en los cefalópodos. En tal caso la medida ciertamente interesante es la supresión de un cierto número de unidades de esfuerzo de pesca, pues ni tan solo el establecimiento de cuotas soluciona la cuestión, ya que en tal caso se consigue que la competencia sea la misma pero en un tiempo menor.

Una pesquería adecuadamente organizada en lo que se refiere a una zona concreta como la que nos ocupa debe estar constituida por unas capturas especialmente importantes de peces pelágicos y semipelágicos mediante los cuales se obtiene gran cantidad de peces, destinados a asegurar la masa de la producción con precios relativamente bajos, con lo que no sólo se aseguran los ingresos suficientes sino que además se suministran factores proteínicos suficientes a una gran masa de la población consumidora. Al margen de esta situación, una parte seguramente podría ser industrializada y conservas, seleccionando lo mejor en cada caso, y el producto menos fino podrá ser destinado a la producción de subproductos de tanta importancia en la alimentación animal y para ciertos menesteres industriales. Tal planteamiento evita el que grandes cantidades de peces sean destinados al subproducto en detrimento del consumo humano. Una segunda faceta lo constituyen los peces que reúnen las condiciones anteriormente mencionadas con capacidad de protección y elevada tasa de renovación. En tales casos estas especies son solamente interesantes cuando tienen tasas económicas muy elevadas y cuando sus oscilaciones económicas se mantienen al margen del poder adquisitivo de la población consumidora; se trata especialmente de crustáceos peneidos y cefalópodos. Resta tan sólo considerar aquellas especies que en general constituyen la parte fundamental en las pescas de arraste: por ejemplo los gádidos y los espáridos entre otras y en especial en la zona que nos ocupa. Estas especies precisamente porque su tasa de crecimiento y reproducción no es en general muy alta y por su enorme exposición a la pesca durante largos períodos, entre los que se incluyen, por su habitat, las formas más juveniles, precisan de un control que afecta a la defensa del stock. La ausencia de los controles produce un doble efecto: por una parte la progresiva esquilmación del stock y por otra, la disminución constante de los ingresos por barco. Estos stocks, una vez deteriorados, son de lenta recuperación y las medidas habitualmente empleadas — tamaño de las mallas, disminución del esfuerzo, etc. — producen resultados satisfactorios, pero en muchas ocasiones se tropieza con dificultades económicas inmediatas que hacen difícil su aplicación.

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1. The main feature of the fisheries in this area is their complexity. This results from the diversity in the nature of resources and demand for fish, in the wide range in the origin and characteristics of fleets engaged, as well as in the objectives and present capabilities of fishing countries. As the overall exploitation become more intrusive, the various groups of countries cannot continue to conduct their operations independently. Fortunately the requirements and objectives of the various participants are not exactly the same and therefore are in part complementary rather than conflicting.

Resources

1. The marine fishery resources of the region from Gibraltar to the Zaire River are impressive. The area includes a region of upwelling and high productivity off the western bulge of Africa, characterized by large stocks of sardine, sardinella, mackerel, and horsemackerel. Bottom fishes include sea-breams, hake, and cephalopods. In the Gulf of Guinea the resource is less and more varied as to species; in several fishing grounds pink shrimps are one of the most valuable resources. Tuna is abundant in the whole tropical Atlantic but surface fisheries are mainly concentrated along the West African Shelf. Total landings of all marine species in 1970 were 2.6 million tons, of which 0.5 million were from south of Cape Verde.

2. The freshwater fisheries especially in swamp areas, are not unimportant in volume and have the advantage of being close to the consumers. These include river fisheries, those of natural lakes like Chad, and those of reservoirs like Volta.

Demand

3. The largest local demand for fish protein is in the countries bordering the Gulf of Guinea, whereas the largest supplies are north of Cape Verde and south of Cape Lopez (Gabon). Although this demand is expected to double, the overall supply seems adequate for the needs of the region. However, serious problems of regional trade, distribution, and marketing need to be solved. This will involve harbors, storage and ice facilities, development of cheap processing methods for fish preservation, and effective transportation to the interior.

4. There is also a demand for the higher-valued types of fish products from this region in countries bordering the Mediterranean, in eastern Europe, in the Far East, and in North America. Both the percentage and the absolute amount of fish taken by long-distance fisheries has increased since 1958; these are 66%, and 1.7 metric tons.

Kinds of Fisheries

5. Artisanal fisheries are still the major sources of sea fish in some countries of the region. The canoes and similar craft that are used have the advantage of not requiring harbors, and their effectiveness is being improved by outboard motors. Freshwater fisheries are almost entirely of the small-scale artisanal type, mostly using traditional gear and craft. However, their capacity is small and better types need to be developed. Medium-sized trawlers and purse seiners are locally based and operate mostly at greater depths than the artisanal fisheries. The Moroccan sardine fishery is large and long-established. The shrimp fishery in the Gulf of Guinea is rather recent, and uses boats similar to those in the Gulf of Mexico. Most of the larger vessels, both trawlers and purse seiners, come from Europe and Far East countries. Tunas are taken mainly by clipper-type ships, mostly operating at a distance from their home ports. Recently converted whaling mother-ships have been used by other countries to catch fish for fish-meal and to process much of their catch.

Utilization

6. With the present rate of fishery development in the area, most of the stocks of major economic importance are estimated to be fully, or nearly fully exploited, and as a consequence are in urgent need of management. Among the heavily utilized stocks are many species in the northern zone—e.g. sea breams, hake, cephalopods, mackerel, and sardinella, most inshore demersal stocks, including pink shrimp in the Gulf of Guinea, and the yellowfin tuna in the oceanic waters. Moderately utilized species include skipjack and bigeye tuna, moroccan sardine, sardinellas south of Gabon, bluefish, bonga, etc. Little-exploited stocks include anchovy, little tuna, and offshore demersal and pelagic (i.e. mackerel and horsemackerel) in the tropical area.

7. Freshwater fisheries, for example in Lake Chad, are fairly heavily exploited.

Development

8. In this region, as elsewhere, it is important that fishery development be approached systematically. All relevant sectors of the economy, as well as social factors, must be given adequate consideration to achieve effective results. This integrated approach, coupled with effective planning machinery, can yield good development and also reduce related economic and social adjustments.

9. Development plans should emphasize increasing participation by local countries, while maintaining full utilization but avoiding overexploitation of the resource potential. While needing adequate technology, financing and expertise, locally-based fisheries would benefit from low labor costs and large potential market. Reduction in costs can also be expected by basing some installations on land rather than on the vessels.

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10. One great need is for training local personnel, not only for mechanized fishing but also in support activities and management roles. At present, locally-based vessels are often manned to a large extent by expatriates, which is expensive for the country's economy.

11. At the same time the improvement of artisanal fisheries must proceed actively. The fact that it is labor-intensive is an advantage in populated areas. Cooperatives are one device for assisting improvement of this sector.

12. It is important that in aid programs of any sort there should be complete cooperation locally and a strong input from the country concerned.

Management

13. The two existing international bodies, CECAF and ICCAT, have made good starts in regulating the marine fisheries. No additional bodies seem to be required nor do the present ones need to be given any new authority. However, as exploitation nears the optimum limit in more and more fisheries there will be need for the application of increasingly intensive management measures.

14. On Lake Chad there is informal cooperation between four countries, and the need for continuing cooperation is obvious.

Research

15. Fishery research centers have been established in a number of African countries. In addition most of the non-African countries engaged in fishing operations in the area are conducting investigations on the fishery resources and their environment.

16. Cooperative research programs have been carried out in the region. The CINECA Program (Cooperative Investigations in the Northern Part of the Eastern Central Atlantic), organized by ICES with the collaboration of FAO and IOC, is now executed by 12 countries, with the objective of investigating the northern up welling and its effects on the fishery resources. In order to achieve its fishery objectives, it would be more effective if more vessels, appropriately equipped, could take part in the acoustic surveys aimed at assessing the coastal pelagic stocks.

17. The present level of research, by both local institutes and expeditionary vessels, is insufficient to solve as speedily as is desired, the problems of intensive exploitation. In addition, although several assessments are already available, they do not always concern the largest stocks, e.g. the coastal pelagic stocks in the northern area. A better balance in the orientation of the kinds of investigations undertaken is required to improve the effectiveness of research. The need for better statistical and biological data on the stocks as well as for their prompt compilation and dissemination among the users concerned has also been stressed.

18. Strong effort should be put into research and development of aquaculture potential, because of the large suitable areas existing in various parts.

19. As time goes on, it is expected that local scientists will increasingly replace foreign experts. In this context the need for training was stressed.

FAO Technical Conference on Fishery Management and Development

TECHNICAL SESSION IV — SECTION 3

Regional and Other Case Studies — Indian Ocean

CHAIRMAN: N. K. PANIKKAR

Management and Development of Fisheries in the Indian Ocean[1]

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Marr, J. C. 1973. Management and development of fisheries in the Indian Ocean. J. Fish. Res. Board Can. 30: 2312–2320.

Development is defined as utilization of a fishery resource to meet the objectives of the government concerned; management is organization of the course of development to meet the socioeconomic objectives and resource utilization policy of government, and to deal with allocation of common-use resources.

The rate of increase in fishery production in the Indian Ocean is slightly greater than the rate for the world as a whole, but the absolute level relative to potential is much lower in the Indian Ocean than elsewhere. Indian Ocean catches by non-Indian Ocean countries amount to about 8% of the total and have been increasing rapidly, a trend that may be expected to continue.

Development of inshore fisheries has been promoted by governments of Indian Ocean countries, the private sector of Indian Ocean countries, the private sector of some non-Indian Ocean countries, and bilateral and multilateral assistance agencies. Development of offshore fisheries, especially for tuna, has been carried out by the longline fleets of Japan, followed by Taiwan and Korea. Governments of Indian Ocean countries show great interest in developing those resources for which there is a world demand, including shrimp, tuna, lobster, cuttlefish, and fish meal. Joint ventures with the private sector of economically developed countries are a common mechanism to develop such resources, particularly those in inshore areas such as shrimp.

Management tends to be concerned primarily with socioeconomic objectives, particularly the gradual upgrading of the artisanal fisheries. However, among existing international management mechanisms are: a bilateral agreement between Thailand and Malaysia, apparently effective in solving local problems; and the Indian Ocean Fishery Commission, an FAO Regional Commission with 31 member nations, of which 19 are Indian Ocean countries. It has a special charge to consider offshore resource management problems and although it has been reasonably effective in identifying these problems the appropriate political decisions will be more difficult to realize.

The Indian Ocean Program arose from the IOFC, is supported by the UNDP as an InterRegional Project, and is executed by FAO. Its purpose is fishery development, promoted through a small professional staff plus consultants. Twenty-six feasibility and other studies have been published and in 1972, the first operational year, the Program initiated or was involved in proposals totalling about $37 million (US).

The need for development is urgent and activities must be timely. Impediments to development include handling-distribution problems; specific bottlenecks, such as lack of ice; lack of infrastructure; transplantation of western fishery science, generally not development-oriented; lack of capital, technology and managerial skills; artificial currency-valuation and import restrictions; and poor communications.

The need for management exists if mistakes made elsewhere are to be avoided. Attention needs to be given to schemes involving artisanal fisheries. Impediments to management include lack of information necessary to decision taking; lack of new methodology applicable in the absence of conventional data; problems of allocation of common-use resources; difficulties in enforcement; and the fear by countries not engaged in a fishery that management schemes will preclude their subsequent entry into the fishery.

L'auteur entend par développement l'utilisation d'une ressource halieutique de façon à atteindre les objectifs fixés par le gouvernement intéressé. Il entend par aménagement l'organisation du processus de développement de façon à satisfaire les objectifs socioéconomiques et à répondre à la politique gouvernementale en matière d'utilisation des ressources et à assurer la répartition des ressources exploitées en commun.

Le taux d'expansion de la production halieutique dans l'océan Indien est légèrement supérieur au taux mondial, mais le niveau absolu par rapport au potentiel de ressources est bien plus bas dans l'océan Indien que partout ailleurs. Les prises faites dans l'océan Indien par des pays non riverains s'élèvent à environ 8 pour cent des captures totales et connaissent un essor rapide, tendance qui se poursuivra sans doute.

Le développement des pêches côtières a été encouragé par les gouvernements des pays de l'océan Indien, par le secteur privé de ces pays et de certains autres non riverains, ainsi que par des organismes d'aide bilaté-

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rale et multilatérale. Le développement de la pêche hauturière, notamment de la pêche au thon, a été l'oeuvre des flottilles de palangriers du Japon et, dans une moindre mesure, de Taïwan et de la Corée. Les gouvernements des pays de l'océan Indien manifestent un vif intérêt envers la mise en valeur de ces ressources, pour lesquelles il existe une demande mondiale; il s'agit notamment des crevettes, des thons, des langoustes, des seiches et de la farine de poisson. Les entreprises mixtes en collaboration avec le secteur privé des pays à économie développée représentent une formule courante pour le développement de ces ressources, en particulier celles des zones côtières comme les crevettes.

L'aménagement vise donc essentiellement des objectifs socioéconomiques, notamment la modernisation progressive des pêcheries artisanales. On peut citer toutefois parmi les dispositifs actuels d'aménagement au niveau international (1) un accord bilatéral entre la Thaïlande et la Malaisie, qui permet apparemment de résoudre avec efficacité les problèmes locaux, et (2) la Commission des pêches pour l'océan Indien (CPOI), commission régionale FAO comprenant 31 Etats Membres, dont 19 sont riverains de l'océan Indien. La CPOI est expressément chargée d'examiner les problèmes posés par l'aménagement des ressources du large et, bien qu'elle ait rempli cette tâche de façon assez satisfaisante, les décisions correspondantes de caractère politique seront certes plus difficiles à mettre en oeuvre.

Le Programme de l'océan Indien a été lancé avec l'aide du PNUD par la CPOI en tant que projet interrégional; il est exécuté par la FAO. Il a pour objectif la mise en valeur des pêches, réalisée grâce aux activités d'une équipe restreinte de spécialistes secondés par des experts-conseils. Vingt-six études de factibilité et d'autres travaux ont déjà été publiés et en 1972, première année opérationnelle, le Programme a donné suite ou a participé à projets pour un montant d'environ 37 millions de dollars E.U.

Il est urgent d'entreprendre des activités de développement et elles doivent être prises à temps. Les principaux obstacles au développement sont les suivants: problèmes de manutention et de distribution; difficultés spécifiques telles que manque de glace; absence d'infrastructure; adaptation de la science halieutique occidentale qui, généralement, n'est pas orientée vers le développement; manque de capitaux, de technologie et de personnel de direction; évaluation artificielle des devises et restriction des importations; insuffisance des communications.

L'aménagement des ressources est nécessaire si l'on veut éviter les erreurs commises ailleurs. L'attention doit se tourner vers des projets faisant participer les pêches artisanales. Parmi les obstacles à l'aménagement, on peut citer la pénurie d'informations nécessaires à la prise de décisions; le manque de méthodes nouvelles pouvant être appliquées en l'absence des données conventionnelles; les problèmes de la répartition des ressources exploitées en commun; les difficultés d'application; les craintes exprimées par les pays ne faisant pas partie d'une pêcherie de se voir ultérieurement exclus de cette pêcherie après la mise en oeuvre des projets d'aménagement.

Por explotación se entiende el aprovechamiento de un recurso pesquero de modo que se logren los objetivos del gobierno interesado en ello. Regular consiste en organizar el proceso de explotación de manera que se logren los objetivos socioeconómicos del gobierno, se tenga en cuenta su política en materia de aprovechamiento de recursos, y se afronte el problema de la distribución de recursos de uso común.

El índice de aumento de la producción pesquera del Océano Indico es ligeramente superior al de la producción mundial, globalmente considerada, pero la cifra total, habida cuenta de las posibilidades, es mucho menor. Las capturas en el Océano Indico de países ajenos a él ascienden a cerca del 8 por ciento del total, han aumentado rápidamente y probablemente seguirán haciéndolo.

El desarrollo de las pesquerías de bajura ha sido promovido por los gobiernos de los estados del Océano Indico, el sector privado de estos países, el sector privado de algunos países ajenos al Océano Indico y diversos organismos de asistencia bilateral y multilateral. La apertura de pesquerías de gran altura, especialmente de atún, ha corrido a cargo de la flota palangrera de Japón, a quien han seguido Taiwán y Corea. Los gobiernos de los países del Océano Indico están muy interesados en explotar los recursos que encuentran demanda en el mercado mundial, entre ellos el camarón, el atún, el bogavante, la jibia y la harina de pescado. La creación de empresas conjuntas con el sector privado de países económicamente desarrollados es frecuente para la explotación de dichos recursos, especialmente los que se encuentran en zonas costeras, como el camarón.

Hasta la fecha, las actividades de regulación tienden a ocuparse ante todo de los objetivos socioeconómicos, especialmente de la mejora gradual de las pesquerías artesanales. De todas formas, entre los acuerdos internacionales ya existentes puede citarse (1) un acuerdo bilateral entre Tailandia y Malasia, que según parece, constituye un mecanismo eficaz para resolver problemas locales, y (2) la Comisión de Pesca para el Océano Indico, comisión regional de la FAO que cuenta con 31 estados miembros, 19 de ellos ribereños del Océano Indico. Esta Comisión se ocupa especialmente de examinar los problemas de regulación de los recursos pesqueros y aunque se ha demostrado razonablemente eficaz en la identificación de los problemas le será algo más difícil llegar a las decisiones de principio necesarias.

El Programa del Océano Indico, organizado por la CPIP, está sostenido por el PNUD, como proyecto interregional, y de su ejecución se encarga la FAO. Tiene por objeto la mejora del sector pesquero, y para ello cuenta con un pequeño núcleo de personal profesional, más diversos consultores. Se han publicado 26 estu-

dios (de viabilidad, etc.) y en 1972, primer año de trabajo, el Programa ha iniciado y participado en propuestas de un valor total de cerca de 37 millones de dólares.

Es urgentemente necesario mejorar la explotación pesquera, pero para ello es necesario actuar tempestivamente. Entre los obstáculos pueden citarse los problemas de manipulación y distribución; algunas deficiencias concretas, como la falta de hielo; la falta de infraestructura; el trasplante de conocimientos pesqueros occidentales, que en general no están orientados hacia la explotación; la falta de capital, tecnología y preparación administrativa; la fijación artificial del tipo de cambio y las restricciones de importación; y la falta de comunicación.

Es necesario aplicar medidas de regulación si se quiere evitar los errores cometidos en otras partes. Hay que prestar atención a programas que participen pescadores artesanales. Entre los obstáculos que se oponen a la regulación figuran la falta de la información necesaria para tomar decisiones; la falta de una nueva metodología que pueda aplicarse aunque se carezca de los datos convencionales; los problemas que plantea la distribución de recursos de uso común; las dificultades que encierra velar por la aplicación de las medidas adoptadas; y el miedo de los países que no participan en la pesquería a que la existencia de un programa de regulación les impida participar posteriormente en la misma.

THE assigned title of this paper would preferably have listed management and development in the opposite order. While development and management are two sides of a coin, management is rather meaningless without development. I take development to mean utilization of a fishery resource to meet the objectives of the government concerned, commonly those that tend to raise the economic level of its people. Various subobjectives may be specified (for example, to earn foreign currency, to produce more protein, or to provide employment). I take management to be organization of the course of development to meet the socio-economic objectives of the government (e.g. to provide employment, to prevent overcapitalization), to meet the resource utilization policy of the government (e.g. to prevent biological overfishing), and to deal with allocation of common-use resources (whether allocation between nationals of a single country or between nationals of two or more countries and hence between governments).

I will consider development and management primarily from the standpoint of the government of an economically developing country, or of a multilateral or bilateral development agency. The development and management objectives of the private sector may differ from those of government. This viewpoint in no way minimizes the importance of the private sector in development and management, and making governmental and multilateral and bilateral activities more relevant to the interests and needs of the private sector would hasten the process of development. Even this Conference does not have the benefit of extensive participation by the private sector.

The last FAO "Technical Conference on Fisheries Management and Development" was held in 1955. World and Indian Ocean catches of marine fishes in 1955 and in 1970 and 1971, the most recently available data, are shown in Table 1. Both the world catch and the Indian Ocean catch have increased almost 1.5 times in this period, with the Indian Ocean rate of increase somewhat higher. As might be inferred, and as pointed out elsewhere (Gulland 1972, Marr et al. 1971), although the rate of increase of the Indian Ocean catch compares favorably with the world rate, the absolute level of the catch is substantially below what could be expected, on the basis of area, in relation to catch from other oceans, productivity, and other lines of evidence. To put it another way, although large areas of the Atlantic and Pacific are being exploited at the upper limits of their productivity, this is not true of the Indian Ocean.

TABLE 1. World and Indian Ocean catches of marine fishes, in millions of metric tons. (Source: FAO fishery statistics)

	1955	1970	1971
World catch	25.4	60.6	59.9
World catch, as % of previous year	–	239%	97%
Indian Ocean catch	1.2	2.8	3.1
Indian Ocean catch, as % of previous year	–	233%	111%
Indian Ocean catch, non-Indian Ocean countries	nil	0.047	0.242
Indian Ocean catch, non-Indian Ocean countries, as % of previous year	–	–	515%
Indian Ocean catch, non-Indian Ocean countries, as % of Indian Ocean total	–	1.7%	7.8%

A recent feature of Indian Ocean fisheries, which is related to the intensive fisheries in other oceans as well as to increasing world demand for fishery products, is the increase in catches by non-Indian Ocean countries; from nil in 1955, their catches in 1971 were almost 8% of the total from the Indian Ocean, and even more impressive is the increase by a factor of five from 1970 to 1971. Although it obviously cannot continue at this rate, the trend may be expected to continue.

Present Course of Indian Ocean Fishery Development and Management

DEVELOPMENT

Fishery development in the Indian Ocean is being stimulated (not listed in any order of significance) by governments of Indian Ocean countries, bilateral projects, multilateral projects, the private sector in Indian Ocean countries, the private sector in non-Indian Ocean countries, and governments of non-Indian Ocean countries.

The location of the responsibility for fishery development in the government structure of Indian Ocean countries is frequently, though not invariably, in the Ministry of Agriculture. Its status in government is generally not high, although at least one Indian Ocean country has a

Ministry of Fisheries and in others Fisheries is a main subdivision in the Ministry of Agriculture. Although there are notable exceptions, it appears difficult to develop a concept of the opportunities and needs for fishery development, prepare a plan for such development, and get it implemented by other parts of the government machinery.

Specific projects for bilateral or multilateral assistance are proposed by governments to the appropriate agency, even though the agency may actually assist in project identification and formulation. These are generally in the areas of training and education, and preinvestment activity; or less commonly in provision of infrastructure. Although projects may occasionally be too successful, i.e. result in over capitalization at the producer level (and perhaps at the processing level) and a reduction in total annual production of the resource, there is commonly a hiatus between the results of the project and application of these results in fishery development.

The private sector in the fishery countries of the Indian Ocean has contributed substantially to fishery development, although sometimes handicapped by lack of capital and technological and managerial skills. Its operations may be less obvious than those of the private sector of non-Indian Ocean countries, but it is responsible for the bulk of production in the Indian Ocean. Most operations tend to be in coastal, relatively shallow areas.

The long-line tuna fleets of Japan, followed by Taiwan and Korea, have, on the other hand, developed the high seas tuna fishery, which extends over most of the Indian Ocean and is carried out almost entirely by their boats. It is likely, however, that fishermen from Indian Ocean countries will take an increasing share in the coming years.

The private sector of Japan has also participated extensively in formation of joint venture shrimp companies. Shrimp tend to occur in territorial waters, and hence joint ventures have been much more common in the shrimp fishery than in the tuna fishery, where they have been formed largely in connection with cold storage and trans-shipment bases.

Some trawling in the Mozambique Channel area by Portuguese and Spanish interests and in the Arabian Sea by Japanese interests may also be mentioned.

In addition to bilateral arrangements in which a number of non-Indian Ocean countries (governments) are involved, the only non-Indian Ocean government actively involved in fishing in the Indian Ocean is the USSR.

The quality and quantity of development activities vary greatly among countries. One common attribute of these activities is the interest in developing shrimp and tuna fisheries. The reasons are obvious; such fisheries are or can be very profitable, and they earn foreign currency. For the same reasons there is interest in lobster and cuttlefish fisheries, and recently in the development of fisheries appropriate to fish meal production. There are also activities that are equally if not more important (soft loans, subsidies, introduction of technological and managerial innovations, etc.), which are effectively upgrading the economic status of the fishermen and increasing supplies and improving the quality of fish in domestic markets.

It is to be expected that these development trends will continue, that fisheries carried out by Indian Ocean countries will expand offshore where there will be competition or conflict with fisheries carried out by non-Indian Ocean countries, and that, as fishing intensity increases, there will be an increasing number of management problems.

MANAGEMENT

The outstanding feature of management in the Indian Ocean is that there is little of it. There are the usual exceptions to a generalization, and one of these is a system in one country of licensing shrimp joint venture companies in such a way as to deal with the three facets of management — socioeconomic, resource utilization, and allocation.

However, if one is optimistic, the outlook for the future of management activities is good, for at least two reasons: first, most of the resource base in the Indian Ocean is not fished at the rate it is capable of supporting, except for some resources already economically, and perhaps biologically, over fished. Second, as compared with the North Atlantic and North Pacific, and with the exceptions noted, there is not a long history of fisheries based on common-use resources by two or more countries. With the apparent increase in the extension of fishery jurisdiction by coastal states, the occasions for potential conflicts in the future will be reduced.

Two existing arrangements for dealing with management problems should be mentioned. The first is an arrangement between Thailand and Malaysia designed to promote their fishing industries. This arrangement or agreement involves a Ministerial Committee, which meets annually, and two sub committees, one on technical cooperation and the other on fishing problems, particularly the violation of the sovereignty of territorial waters of one country by fishing boats of the other. This arrangement has resulted in a reduction in violations of territorial waters, a reduction in the duty on *Rastrelliger* imported into Thailand from Malaysia, and an increase in technical cooperation and interchange. In short, it has provided an effective mechanism for dealing with trying problems.

The second arrangement is the Indian Ocean Fishery Commission, a regional commission formed under Article VI of the FAO Constitution. The IOFC was formed in 1967, first met in 1968, and now has 31 Member Nations, 19 of which are Indian Ocean countries. The objectives of the Commission are:

"(a) to promote, assist and coordinate national programs over the entire field of fishery development and conservation; (b) to promote research and development activities in the area through international sources, and in particular international aid programmes; (c) to examine management problems with particular reference, because of the need to take urgent action, to those relating to the management of offshore resources." (FAO 1968).

Subsidiary bodies of the Commission have been established as follows:

Name	Date	Number of meetings	Status
IOFC/IPFC Joint Working Party of Experts on Indian Ocean and Western Pacific Fishery Statistics	9/68	3	continuing

Name	Date	Number of meetings	Status
Working Party on Stock Assessment in Relation to Immediate Problems of Management in the Indian Ocean	9/68	1	replaced by Nos. 3 and 4
Working Party on Stock Assessment of Shrimp in the Indian Ocean Area	10/70	1	continuing
IOFC/IPFC Working Party of Scientists on Stock Assessment of Tuna	10/70	1	continuing
Committee on the Management of Indian Ocean Tuna	9/68	3	continuing
Committee on the Management of Gulf Shrimp	9/68	0	in suspense
IOFC Executive Committee for the Implementation of the International Indian Ocean Fishery Survey and Development Programme	10/70	3	continuing
Committee for the Development and Management for the Fishery Resources of the Gulfs (Gulf of Oman and Gulf lying between Iran and the Arabian Peninsula)	10/72	0	continuing

While the bodies which relate to management have worked well with respect to gathering and analyzing existing data, decision-making based on such analyses has not proceeded as rapidly. The task of understanding what has happened to the stocks (particularly of tunas) has proceeded quite well, but as emphasis has passed from understanding to political decision taking, progress has slowed down. One Indian Ocean country has joined some non-Indian Ocean countries in a position which, whatever its logical rationale, has had the practical effect of delaying any management decision (which is in itself a form of decision) with respect to the longline tuna fishery. I infer that the reason for this is that the Indian Ocean country wants to enter this fishery, is not yet able to do so, and fears that a management scheme adopted prior to its entry into the fishery may act to preclude its subsequent entry.

The Indian Ocean Program

Also arising from the Indian Ocean Fishery Commission is the International Indian Ocean Fishery Survey and Development Program, or the Indian Ocean Program as it is more commonly known. This is funded entirely by the United Nations Development Program as an Interregional Project, with the Food and Agriculture Organization of the UN acting as the Executing Agent. Phase I of the Program consisted of 2 years (1970 and 1971) of information gathering, problem identification and planning, and 1 year (1972) of operations. Phase II, which will be considered by the UNDP Governing Council at its January 1973 Session, will provide for continued operations through 1976. The total cost for the 7-year period, if Phase II is approved, will be about $2.5 million (US).

The broad objective of the Program, to quote the Project Document (the statement forming the agreement between the Indian Ocean countries, UNDP, and FAO, which specifies the nature and scope of the Program), is "... fishery development in the sense of contributing to general economic development, including especially the development and introduction of rational management systems and methods, and the stimulation of investment, from international as well as national sources, in the fishery sector; to provide a source of foreign exchange; to contribute to meeting various socio-economic needs; to provide a source of protein, and to lead to generally increasing standards of living and to the diffusion of economic well-being throughout the population."

The immediate objective of the Program "... which is primarily investment-oriented is to assist the countries around the Indian Ocean area in achieving long-range coordinated fishery development activities through the program staff activities and by conducting development-oriented surveys in selected areas in the Indian Ocean, and to promote rational utilization and management of resources in order to avoid overcapitalization and over-exploitation.

"In particular the objectives are: (i) to review and coordinate all fishery development programmes in the area in the framework of the Indian Ocean Programme; (ii) to facilitate the flow of information to make project operations more effective and to avoid duplication of effort; (iii) to identify and assist in development of country and regional pre-investment projects; (iv) to prepare investment feasibility studies and to liaise with potential investors such as private industry, governments and development banks; (v) to train personnel; (vi) to monitor and assess work done by various projects developed under the Indian Ocean Programme; (vii) to supervise and coordinate generally resource surveys[2] which will mainly be implemented by mobilizing resources, particularly vessels and technical staff, through voluntary contributions from member countries of the Commission and by coordinating relevant activities of existing projects, as well as those of new projects to be developed; to conduct surveys under UNDP funding."

The Program operates through a core staff of six professionals (of whom three are recruited and three will be added during 1973) of different disciplines, plus consultants in additional specialities or for specific tasks as required. Under the Program, 26 studies have been published in the FAO series "IOFC/DEV," four are in press, and others are in preparation. In addition, in some cases special unpublished reports are made to governments or institutions that request them.

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[2] "The term "resource surveys" is used throughout in a very broad sense to include surveys which provide estimates of the magnitude of resources (sometimes known as "exploratory fishing") and surveys which provide information on catch rates (sometimes known as "experimental fishing"). The objective of resource surveys is to provide resource information pertinent to fishery development."

The Indian Ocean Program is not operational in the same sense as is an individual project in one country; rather it will stimulate the identification, formulation and funding of such projects. Attention is being given to ensure that such projects are development-oriented and that project results are integrated in the development-investment process. The Program is more fully discussed by Marr et al. (1971).

The services of the Indian Ocean Program, available on request subject to limitations of staff and budget, are being increasingly utilized by governments and institutions. During 1972 the Program was either directly responsible for, or deeply involved in, proposals of various kinds in the total of about $37 million (US). If these all come to fruition, they will involve about $11 million (US) in private or government investment, about $6 million (US) in Government contributions in kind, about $11 million (US) from bilateral sources, and about $8 million (US) from the UNDP.

Features and Obstacles in Indian Ocean Fishery Development and Management

DEVELOPMENT

It is difficult to separate features and obstacles, because a feature may also be an obstacle. However, two features will be discussed — urgency and timeliness — then features which are generally also obstacles.

". . . one cannot get . . . far into development in the Indian Ocean region without being overwhelmed by a . . . sense of urgency. One has only to recall . . . recent . . . events in the Indian Ocean region to realize that time is of the essence. . . . those who are involved in development activities have to take decisions on the basis of far from complete information. Indeed, because of this urgency it is essential to develop rapid, innovative ways of looking at old problems." (Marr 1972b)

Successful development activities are those which are timely. This may be a truism, but it is sometimes overlooked. There is currently a great deal of world market interest in the Indian Ocean as a source of skipjack tuna. Because of this interest, additional skipjack fisheries are being and will be developed in the Indian Ocean. Less than 5 years ago, world demand for skipjack was being reasonably satisfied from other sources, and it was not timely to develop the Indian Ocean skipjack resources. A similar statement could also be made about fish meal, although this situation may be more complicated. One other example of a timely development activity may be cited, farther afield geographically but related to Indian Ocean fisheries. This is the Korean/UNDP/FAO Deep Sea Fishing Training Center in Pusan, a highly successful Centre to train tuna longline fishermen. One of the main reasons it was successful was the great demand for its graduates to man the growing Korean longline fleet. It was timely. There are examples of projects which were failures because they were not timely, which I need not cite.

Although it is sometimes said that lack of resource knowledge is a major impediment to fishery development in the Indian Ocean, which is true for particular areas and species, many other conditions are more important at this stage of development. For example, a great deal of value, quality, and quantity is lost by what happens, or does not happen, to the fish after they are removed from the water. Inappropriate handling, including inadequate use of ice, is a major impediment to full utilization of the present catch, not to mention expanded catches.

There are frequently specific bottlenecks in fishery development, and a common one is unavailability of ice. In one country the price of ice is about four times what it should be, and its use is prohibitive in the fishing industry. Perhaps the simplest thing which could be done to stimulate fisheries in this country would be to make ice available at realistic prices, either through cooperative development or by direct government intervention.

Another impediment to development is frequently inadequate or completely lacking infrastructure. Some kinds of infrastructure, such as major harbors and highway or rail networks, are very costly, so that they can rarely be justified on the basis of fisheries alone. Fortunately these kinds of infrastructure are frequently necessary for economic development in general, and those individuals involved in fisheries must be alert to make their needs and support known to the appropriate planning bodies and world and regional banks.

One major impediment to fishery development, especially as this relates to the activities of governments, I have come to appreciate fully only in the last year or two and is not generally recognized. This is the transplantation of fishery science and administration, from the western highly economically developed countries to the economically developing countries, without taking into account differences in the new environment. (In fact, some aspects of what follows may also be considered to be impediments in the developed countries, but this point is not at issue here.) As Wilson (1971:123) has put it, there is ". . . the need, not always rationally accepted by either the foreign expert or his eager pupil, for the alien technology to be married to local conditions."

There are three reasons why fishery science is an impediment to fishery development. These are:

Fishery science as a discipline has developed and been brought to its present level primarily in northern Europe and North America. (This is not to ignore substantial contributions from Japan and the USSR, considered later.) In these areas, fishery development has been primarily brought about by the private sector. Fishery scientists, generally in the employ of national or local governments, have thus been oriented toward the accumulation of knowledge about fishes — spawning, growth, migrations, etc. — and toward management problems including stock assessment. This is quite a different orientation than preoccupation with development problems.

In addition to this orientation toward biology and management problems, many fishery scientists in the developed countries have, during their formal training, been given or acquired the belief (sometimes at the subconscious level) that fishery scientists in the employ of government organizations are inferior to their colleagues in the same or other disciplines who are in the employ of academic institutions. Thus there is a tendency to compete with academic colleagues on academic terms; that is, by the publication of good scientific papers in good scientific journals. Work on the solution of development problems, which have a large (if not complete) element of practical application, is, in this context, not attractive to the fishery scientist nor likely to advance his career.

Perhaps the most widely held article of faith on the part of fishery scientists is "... that variations in the distribution (and abundance) of fishes are greatly influenced or controlled by variations in the environment and ... by monitoring the environment we would be able to forecast the distribution (and abundance) of fishes. This faith in the influence of the environment is obviously justified for extreme conditions and is probably justified ... for conditions less than the extreme. However, instances ... are not very common. Conceptual models, which can be tested, of how the distribution and abundance of the fish population are imbedded in the environmental matrix are needed" (Marr 1972a), but fishery development projects are not the place for development of such models.

Fishery administration may be an impediment to development for the same reasons, since the fishery administrator is frequently an ex-fishery scientist.

The economically developing countries have tended to look for leadership and assistance in fishery development to the economically developed countries, just as they have in other fields. Unfortunately the circumstances described above — the orientation toward biological and management problems, the attention to good science, and faith in the resource-environment relation — have been passed virtually unchanged to the developing countries through the mechanisms of professional education in the developed countries and technical assistance experts from the developed countries. (One may note the much closer relation between fishery science and development in Japan, and especially in the USSR.)

Thus, I have concluded that in the short term the transplantation of "conventional" fishery science and administration from the developed to the developing countries is an impediment to fishery development. In the medium and long-term, of course, much of fishery science will be useful, if not essential, particularly in dealing with management problems, but only if the transplantation is truly made in the context of the real needs of the developing countries. As a consequence of this short-term deficiency, the pertinent fishery development problems are not solved, nor in some cases even identified, and the ability of the fishery agencies to influence planning and fiscal bodies is low indeed.

I may close this particular point with mention of a particular country which has every known development problem in abundance: overcapitalization in some areas but great underdevelopment in others; inadequate or absent infrastructure of all kinds; inadequate boats; lack of capital, etc. The Department of Fisheries is adjacent to the main fishing harbor, and in plain sight of many of these problems and in full knowledge of all of them sits one of the professional staff, engaged in a study of the taxonomy of copepods.

Cultural characteristics may be an impediment, as for example in those countries in which fish are not eaten or where there is no sea going segment of the population; if there is, fishermen are at the lower end of the social scale. The reverse is true, of course, where fish is the major source of protein in the diet, or where the people are traditionally seafaring.

The lack of capital, technology, and managerial skills are traditional barriers to development in areas which may have an abundant labor supply and a substantial resource base. A well known device for bringing these essential components together is the joint venture, in which the missing ingredients are supplied (usually) by the private sector in an economically developed country. The partner in the company formed in the developing country is usually the government or a quasi-governmental corporation, but may also be from the private sector there. These are useful devices, particularly if there is a large training component and provision is made for the operation eventually to pass entirely to the developing country on some mutually equitable basis. There are also pitfalls, of course. These include the local official in the host country, who may put his own interests ahead of those of the joint venture or his country, and the private interest from the developed country, which may prefer to take its profits through an exclusive marketing arrangement to the detriment of the fiscal performance of the joint venture.

The formation of joint ventures is related to two other matters. The first of these is the problem of how to develop Indian Ocean fisheries for the benefit of Indian Ocean countries. While all countries are free to fish on the high seas, of course, multilateral and bilateral agencies as well as the Indian Ocean countries see little point in carrying out development work, if it is not for the benefit of the Indian Ocean countries. Joint ventures obviously are a mechanism by which the interests of Indian Ocean countries and non-Indian Ocean countries can be mutually served.

As a second point relating to joint ventures, political instability, whether real or imagined, inhibits investment. Fisheries tend to be a high-risk business, and if the potential investor fears that the Government is likely to change to one less favorable to investment, or that his investment may be nationalized with inadequate compensation, then he will not be inclined to make the investment.

Even though lack of capital inhibits fishery development, overcapitalization, of which there are already examples in the Indian Ocean, is also a problem. Overcapitalization has been discussed at length by Gulland (1971) and others. In brief, when a fishery is overcapitalized the same or even increased production could be obtained with fewer boats. And, of course, overcapitalization may also occur at the processor's as well as at the producer's level. The amount by which a fishery is overcapitalized is the amount lost to other more productive forms of investment. Consideration of this problem must be tempered in most Indian Ocean countries by the existence of expanding work forces and the need for increased employment opportunities.

In a few Indian Ocean countries currency is officially valued at an artificially high rate. If enterprises in the export business have to convert their foreign currency earnings at the official rate, the profit margin is more than eroded. Various devices are used to ameliorate this penalty (e.g. use of a specified fraction of foreign currency earnings to import necessary supplies and equipment), but the entrepreneur operating under this handicap cannot compete with others operating elsewhere under conditions of a freely convertible currency. As might be expected, this situation may lead to undesirable practices such as underinvoicing. A more widespread problem is restriction of imports because of unfavorable trade balances. This generally works a hardship on the fishing industry, which must usually rely on imports for engines, synthetic nets, diesel fuel, tinplate, refrigeration equipment, etc.

A further impediment to fishery development in the Indian Ocean (and elsewhere) is that all concerned with fishery development do not make a realistic enough case for it. This case must be made with the economists and planners of planning bodies and funding institutions, who must decide as to which among many development alternatives to pursue. We may make unrealistic claims on the basis of a program of conventional (western) fishery science; it does not take an economist to perceive the non sequitur in this line of reasoning, but economists are rather good at it. Or we may fail to make a realistic appraisal of development possibilities; we fail to specify what needs to be done to bring about such development now; and we almost always fail to indicate the consequences of failure to follow a reasonable fishery development program (e.g. what would be the cost of providing alternative sources of protein?).

Perhaps related to this is inadequate communication — inadequate communication between government, the private sector, and development agencies, and frequently within government. This is perhaps most obvious in the frequent unawareness on the part of government and development agencies of the needs of the private sector, as reflected in the design of development projects and in the noncommunication of project results in a meaningful and timely form to the private sector.

As a corollary, it appears that governments could hasten the development process by ensuring or at least inviting greater involvement of the private sector. Governments are generally concerned with the problems of artisanal fishermen and, with the usual exceptions, much less so with tieing the artisanal fishermen into a vertically integrated development program involving a higher degree of mechanization and organization. The reference to the private sector is in no way intended to ignore those countries with planned economies. There is still the need to upgrade the artisanal fisheries, rather than to shield them, to promote vertically integrated development, and to mold the development plans to the practical ends indicated by the choice of objectives.

It has been pointed out many times in recent months that, in spite of all the resources that have been put into development assistance, the gap continues to widen between the developed and developing countries, and between the "haves" and "have nots" within the developing countries. I wonder if the latter is not a bit simplistic. I have seen many fishing ventures in Indian Ocean countries in which, to be sure, the entrepreneur is making a profit — perhaps even a handsome profit — but so too are the fishermen and the workers in the processing plants, who may have full employment at relatively good pay scales for the first time in their lives. And this does not take into account the multiplier effect of such ventures. While I have no a priori reason to assume that the fishing industry is any different in this respect than other common and larger industries, it would be useful to study carefully a few fishing ventures in order to determine what the dispersion of earnings is and the extent of the multiplier effect.

MANAGEMENT

At the outset I defined management as the organization of the course of development in such a way as (1) to meet the socio-economic objectives of the government, (2) to meet the resource utilization policy of the government, and (3) to deal with the problem of allocation. I also remarked that a feature of management in the Indian Ocean is that there is not much of it. This is certainly true insofar as (2) and (3) are concerned, but it should be made clear that most management effort and concern of government at this stage is with (1). Efforts in this area are largely concerned with upgrading the artisanal fisheries by successive stages, each involving a rather modest increment and/or protecting artisanal fisheries from real or feared effects of more highly mechanized fisheries, which may be developing in the same geographic area but independently of artisanal fisheries. With some notable exceptions, and these relate mostly to fisheries with products in demand in the world market, there has not been as much effort directed to the development of mechanized "modern" fisheries, although such development is the medium- or long-term objective of most governments. As a reasonable middle course of development, one wonders why there has not been more attention devoted to vertically integrated development schemes which involve the artisanal fishermen, rather than leaving them in the anomalous position of needing protection from development.

With respect to (2) and (3), there are a number of features and obstacles to management in the Indian Ocean, some of which are not unique to that area. With exceptions, mostly rather localized, there is not yet a broad need for management except the need to start now in order to avoid the pitfalls encountered in the Atlantic and the Pacific. A major impediment is frequently lack of information on which to base management decisions. This need can only be met by instituting information-gathering systems (relevant to the problems) and, of equal or greater importance, the development of new techniques for examining the problems involved. A further requirement incumbent on those involved (the officials whose responsibility it is to take the decisions and the fishery scientists whose responsibility it is to provide information and sometimes advice) is the realization that timely decisions have to be based on the information at hand and not on some perfect or nearly perfect ideal. As indicated earlier, deferring decisions pending the availability of the ideal is in itself a form of management decision.

Perhaps the major obstacle to management in the Indian Ocean is the same as the major obstacle elsewhere in the world; how to solve the problems attendant to exploitation of common-use resources — the problem of allocation. As Rothschild (1972) has put it: "It appears that the principle of ownership of fish stocks will be required so that these stocks can be effectively utilized. It makes little sense to talk of effective utilization without effective management, and effective management is most hopeless without some concept of ownership." Establishing a concept of ownership may be easier in the Indian Ocean region than it is in some parts of the world, since, in fact, the concept of ownership already exists in many countries at the level of the fishing community.

The problem of allocation and ownership, at least between countries, is related to the width of the territorial seas and contiguous fishery zones; the situation is in a state of flux which, it is to be hoped, will be resolved by the forthcoming UN Law of the Sea Conference. In the meantime, whether coastal jurisdiction will be extended does not appear to be the question, but rather to what extent and at what time and in what form it will be extended.

Related to both management in general and allocation in particular, is the increasing production in the Indian Ocean by non-Indian Ocean countries. While no one questions the right of all countries to fish on the high seas, the Indian Ocean countries tend to regard themselves as coastal countries with respect to high-seas fisheries in the Indian Ocean, particularly those carried out by non-Indian Ocean countries. In any case, this additional fishing is a potential source of conflict and will have to be taken into account in management schemes.

Some local situations in which countries are not on good terms for reasons having nothing to do with fisheries may, as a consequence, make it difficult or impossible for the countries concerned to get together on common management problems and needs.

A difficulty in carrying out some management programs may be that of enforcement, a not uncommon situation.

A final management obstacle may be mentioned. Needed international management action may be resisted by coastal countries not yet involved in the fishery in question, because of their simultaneous desire to enter the fishery at some future time and fear that a management system instituted now may preclude their subsequent participation in the fishery. This suggests that management schemes, if they are to be realistic and acceptable, must make adequate provision for future participation by coastal countries wishing to enter the fishery.

Conclusion

The rate of growth of landings from the Indian Ocean compare favorably with rate of growth of world landings in general. The base level in the Indian Ocean is much lower, however. Catches in the North Atlantic and North Pacific are much closer to estimates of maximum sustained yields for these areas than in the Indian Ocean. It may be expected, therefore, that rate of growth in the Indian Ocean will, in the next few years, exceed that of the world in general. Related to this situation, it may also be expected that the fraction of the Indian Ocean catch taken by non-Indian Ocean countries will increase.

Development activities in the Indian Ocean are being carried forward by the governments of Indian Ocean countries, by the private sector in those countries and, to a lesser extent, by the private sector in some economically developed countries, by multilateral agencies, and by bilateral agencies. As development activities pass from the stage of resource surveys to the more complicated subsequent stages, they become more difficult; there are problems in ensuring not only that the important weak links in the development chain are identified and attacked, but also in conveying results to the private sector in a timely and usable manner.

Management activities, that is, the organization of the course of development so as to (1) meet the socioeconomic objectives of the Government, (2) meet the resource utilization policy of the Government, and (3) deal with the problem of allocation, are, with some notable exceptions, concerned largely with (1). There is a need for vertically integrated development schemes which involve artisanal fishermen. There is a great need for development of innovative ways of examining management problems so that decision-taking can be improved, even in the absence of data conventionally considered to be essential. The greatest management problem is that relating to exploitation of common-use resources.

While management problems may represent the greatest challenge in the whole complex of Indian Ocean fishery development and management, they also offer the greatest opportunity. They offer this opportunity because most of them have not arisen yet, or at least are mostly not present in the form of full-blown crises. Because of this fact, they may not be dealt with until they are in a crisis stage, as is common elsewhere in the world, unless the Indian Ocean countries and non-Indian Ocean countries fishing there are able to forego possible short-term gains in favor of long-term benefits.

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Planning Criteria for Large-Scale Fisheries Development with Special Reference to the Indian Ocean[1]

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Criteria for large-scale fishery development are determined by motives of the developer, which are primarily economic. Economically viable fishery developments invariably have positive social side effects, whereas socially oriented developments seldom have positive economic results.

Primary criteria for development are: species of fish available; the location, size and behavior of the stocks; and ultimately, the unit annual average catch rate of the "best boat." Primary criteria also include hospitality of the riparian state, as measured by its policies and their implementation, the intensity of economic nationalism, and political stability; and the nature of the people, their industriousness, and the ability of the society to absorb capital. The last is a major consideration.

Secondary criteria include such physical considerations as crew amenities, vessel support facilities, communications, and transport.

Tertiary criteria include the overall size of the project, the dimensions of the market, the nature of competition, the possibility of overcapitalization, and, ultimately, luck and the behavior of humans and fishes.

Les critères régissant la création de pêcheries de grande envergure dépendent des motifs du promoteur, qui sont essentiellement économiques. Si, à toute entreprise de pêche économiquement rentable, s'associent invariablement des avantages sociaux concrets, il est rare que des efforts déployées à des fins sociales donnent rarement lieu à des résultats positifs.

Pour créer une pêcherie, il faut tenir compte en premier lieu des espèces de poissons disponibles, de la situation, de l'importance et du comportement des stocks, et enfin du taux moyen de prises annuelles du "meilleur navire." Il faut aussi considérer en premier des facteurs tels que l'hospitalité de l'état riverain, selon qu'elle ressort de ses politiques et de leur application, l'intensité du nationalisme économique, la stabilité politique et, sur le plan ethnique, la nature de la population, sa capacité de travail ainsi que l'aptitude de la société à absorber des capitaux. La disponibilité de capitaux joue un rôle majeur.

En second lieu, on doit faire entrer en ligne de compte des considérations matérielles comme les facilités pour les équipages, les installations de soutien des navires, les communications et les transports.

En troisième lieu enfin, il faut tenir compte de l'ampleur générale du projet, de l'importance du marché, de la nature de la concurrence, des possibilités de surcapitalisation, du facteur chance et du comportement des êtres humains et des poissons.

Los criterios para el desarrollo pesquero en gran escala están determinados por los motivos del organizador que, en primer lugar, son económicos. El desarrollo pesquero viablemente económico tiene siempre un efecto social positivo, mientras que el orientado hacia el aspecto social pocas veces da resultados económicos.

Los criterios primarios para el desarrollo son los relativos a las especies de peces, situación, talla y comportamiento de las poblaciones y, por último, el índice medio de capturas anuales de la "mejor embarcación." Entre los criterios primarios también figuran la hospitalidad del estado ribereño, en función de sus políticas y su ejecución, la intensidad del nacionalismo económico, la estabilidad política y otros rasgos distintivos, como la naturaleza del pueblo, su laboriosidad y la capacidad de la sociedad para aprovechar el capital. También es asunto de enorme importancia la disponibilidad de capital.

Los criterios secundarios incluyen consideraciones físicas, como diversiones de la tripulación, medios de apoyo a las embarcaciones, comunicaciones y transporte.

Entre los criterios terciarios figuran el tamaño total del proyecto, las dimensiones del mercado, la naturaleza de la competencia, la posibilidad de una super capitalización y, por ùltimo, la suerte y el comportamiento de los hombres y de los peces.

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PLANNING is the process by which a speculator (Latin speculare — to see ahead, to explore) hopes to reduce his errors, to predict with some accuracy the outputs which will result from certain inputs, and to arrange the latter so as to maximize the former. Criteria are his stock in trade.

Criteria, however, vary among people and situations, and motive determines the types of criteria. Thus, the essential general question is motive, or purpose — Is it ethereal or temporal, social or economic?

Successful projects which have an economic purpose invariably have a social spin-off. They create employment, foreign exchange, worker upgrading, expanded opportunities, and inject vitality into what, in underdeveloped societies, is often a somber and listless economic scene.

The converse is not true, however. A socially motivated enterprise is not necessarily economic. Oft times better training in the absence of employment is a drain, and improved methodology in the absence of a system of rewards acceptable as incentives to those concerned will produce in the system only an increase in leisure time rather than an increase in the output of goods and services.

Thus the developer must determine whether his primary purpose is social or economic. A lack of conscious purpose on his part or a confusion of basic objectives can quickly lead into the mire. This paper is directed toward large-scale development. The use of capital is therefore implied which, in turn, requires a return over a period of time. Thus, within the scope of these opening paragraphs, the material to follow is related to enterprises whose essential purpose is economic.

If we consider primarily the Indian Ocean we include a vast region characterized more by social need and potential development opportunity than hard accomplishment; by indigenous, artisanal existing fisheries rather than organized industrial enterprises (with a few major exceptions such as tuna longlining and shrimp trawling); and by indicated riches rather than proven returns.

Since the author is associated with a commercial fishing company and has from time to time acted as consultant to a number of national and international agencies, there are some constraints on the comments contained herein.

The Developer

The developer consciously or unconsciously will assess himself, his qualifications and his motives and will establish and assess criteria according to his competence and needs, the latter already established as primarily economic. His qualifications may be: command of capital; special expertise in catching, processing, distribution, and marketing, or a combination of these; special knowledge of a stock capable of development; those of an entrepreneur, meaning one who has the capacity of bringing the necessary capital, expertise, permissions, and organization to bear on an identified goal; the owner of a resource, i.e. a nation or state.

The developer, whether he be an individual, a corporation, a state, or a nation, then attempts to complete the jigsaw puzzle, to fit together the various components of the situation, including his expertise and competence, in such a manner as to complete an economic unit. This he does by aggregating known facts, suspicions, witchcraft, blending them into a question to which the answer is either a "yes" or a "no," viable or not viable.

Primary Criteria

STOCK

A large-scale fisheries production development is sufficiently complicated without adding to it the complication of market development. Therefore the species to be sought are those for which there is an established market of substantial proportions, preferably international. The species which qualify are not numerous. Some, with an indication of their general area of availability, are indicated:

Species and locations — Tuna — general, with skipjack concentrations in Indonesia, the Maldives, etc.; Shrimps — Persian Gulf, Malagasy Republic, India, Thailand, Indonesia, Malaysia; Rock lobsters — general, with few notable concentrations; Tiny lobsters — western limits of Arabian Sea and Gulf of Aden; Cephalopods (octopus and squids) — Arabian Sea, Gulf of Aden; Mackerel — India, Sri Lanka, and general; Clupeids (sardines, sardinellas, anchovies) — East Java, Southwest India, Gulf of Aden, Straits of Hormuz, Mekran Coast, Somalia, the Philippines.

Size of stock — Since development in a remote area is difficult and costly, the stock must have promise of significant strength to qualify for consideration. It must be above critical mass. With certain exceptions small stocks must be left for indigenous fishermen; they do not warrant the major effort needed to bring them into development, even if indicated initial catch rates are satisfactory.

Catch rate — The annual unit catch is the single most important factor in the feasibility equation. Continuously variable, it is difficult to determine precisely. It rises or falls with the changes in natural factors affecting recruitment and reproduction of the stock; it varies in accordance with intensity of fishing effort applied and, above all, with the skill, industry, and acquisitiveness of the skipper.

Prediction, in the absence of an established industrial fishery, is achieved by one of two means, namely:

Directly — This is done by the use of commercial catchers thus determining the catch rate by direct measure. This is comparatively simple and easy to do for shrimps, or for tunas that are available to longline or pole and line boats. The catcher can preserve its output on board by freezing and thus operate independently for a substantial period. This has been done with shrimp development in Indonesia, and with skipjack and yellowfin tuna development generally.

Indirectly — For industrial pelagic fisheries, especially clupeids, the determination of catch rates is not so simple nor is the selection of the best vessel quite so uncomplicated. Both of these depend on shore facilities capable of processing sufficient quantities to enable the "best vessel" to produce at maximum daily rate or reasonably close to it. Therefore some indirect method of appraising the annual and daily rates is desirable, one which will avoid a major capital commitment until the catch rates to support it have been reasonably well established.

Such indirect methods include sonar surveys or aerial surveys with accompanying test catching to determine school size and species, and observations on indigenous fisheries.

Example—A sonar survey with test catching was a major component of the FAO/UNDP program being concluded in the Gulf of Aden. Under that program a single vessel, operated by a competent and experienced skipper and equipped with sonar and purse seine, has for several years methodically examined various pelagic stocks and established their distribution, seasonality, migration patterns, and some rough measure of daily and annual abundance. The result of that effort is such that fairly intelligent judgements with regard to returns may now be made; constrained by the fact that the survey has been proceeding for only 2 or 3 years and the highly variable upwellings of the region may well cause short-term variations in abundance of substantial proportions. That is, the normal wide variables in a pelagic fishery related to changes in the environment from one year to the next are extraordinarily wide in that region.

Example — Aerial surveillance of several specific areas of New Zealand waters has been carried out on a regular planned basis by both private institutions and by government, each accompanied by a test catching program. Reasonable judgments of "best boat" catch rates can be made based on that work.

Example — As an example of indirect assessment, one may look at the catch statistics for Indian oil sardines on the southwest coast of India, match those statistics with observations of the primitive, short-range ineffective fishing effort applied to the stock, determine the seasonality from the performance of that indigenous fishery, and postulate within reasonable limits the catch rates for specific modern equipment which might be applied there.

For some species the appraisal is not so easy. The skipjack potential by purse seining in the Sulu Sea is difficult to determine indirectly, as this species is often difficult to catch although abundant; when catchable it can show a high rate by this method. The degree of skill of the master and quality of the equipment are major factors in the equation, and these are costly assets to risk. Without risking the best of them, the results are inconclusive. Establishing the unit catch rate in this case requires a high order of courage, conviction, and willingness to accept high costs.

In the end, any assessment of unit annual catch rate made in advance of establishment of a multi-unit commercial fishery is, whether direct or indirect, only valid within wide limits. The natural behavior of stocks, availability of gear and skippers, and effect of increased effort on both searching and stock strength, all conspire to make the assessment, at best, a broad appraisal. The unit catch rate is dependent on the abundance, seasonality, and behavior of the stock and the nature of the vessel and crew.

Since the "best vessel" for any particular task is determined by daily catch rates, frequency and duration of voyage, range, and dispersion of the stock — all related to costs and returns, from which are deduced vessel size, power, range, carrying capacity, etc. — an indirect determination of catch rate becomes an arbitrary attempt to break the "chicken and egg" cycle. The specification of "best vessel" becomes much more subjective than if the direct measurement is employed, since the latter is essentially an empirical solution of the equation.

Crew capability is probably the greatest single factor in determining catch rate in an established fishery among similar units. Since, however, that factor is difficult to assess in advance, the planner can deal only in averages and means, with the hope that, in the implementation phase, he will be fortunate or wise enough to enlist the support of extraordinarily sagacious, industrious, disciplined, knowledgeable, and acquisitive masters and crews.

Hospitality of the Riparian State

Coastal species development is largely determined by the quality of the stocks and the hospitality of the riparian state. Some states are inordinately suspicious of foreigners, wish to retain their ocean wealth for the indigenous fishermen, are limited by noneconomic objectives, or embraced by a bureaucracy which, although incapable of initiating entrepreneurial action, is extraordinarily efficient in suppressing it when initiated by others, often with the sole purpose of justifying the existence of that bureaucracy itself.

Hospitality of the riparian state can be measured against specific subcriteria:

POLICY FORMULATION, ACTIVE OR PASSIVE?

Example — Indonesia has an active, two-phase, deliberate development policy. Phase I is designed to initiate activity. It provides that foreign entrepreneurs may stake a specific developmental area, subject to certain conditions, fish it for a period sufficient to determine its productivity with their vessels and personnel brought from abroad, and then decide whether they wish to stay or leave. On election of the former, they are required to nationalize their venture and have a share placed in the hands of Indonesians. They then qualify under the foreign exchange rules for special privileges with regard to repatriation of profits, etc. Phase II will be framed to increase the value added in Indonesia by the harvesting of fish. It is noteworthy that Phase I has been extraordinarily successful and has induced a number of joint ventures in shrimp, tuna, and various others.

Certain other states, however, which have abundant resources have no deliberate policy of development and, as a result, are stagnant.

POLICY IMPLEMENTATION

Despite the formulation of phrases designed to convey the impression that the country aspires to the development of its fish wealth, the policy may be ineffective for a number of reasons including:

Conflicting policies — These occur where foreign ventures are limited to minor equity positions in development enterprises and domestic entrepreneurs are incapable of bringing enterprises to fruition. The conflicting policies make a mockery of the development ideal.

Example — One country has a serious foreign exchange problem, an uni-based economy, a clearly defined underdeveloped fisheries resource of substantial proportions, an enunciated development policy, and a set of rules which, in effect, exclude foreigners. Domestic entrepreneurs, after some years of intelligent effort, have not succeeded in making any marked development impact.

Thus development policy and the "nationals only" policies are in conflict and as a result, development has been inconsequential.

The bureaucracy — Often the underdeveloped societies are old societies with an ingrained administrative apparatus which has generated sufficient rules to clog the simplest, most clear-cut, and forthright development.

Example — One competent North American firm determined some time ago that it could earn profits for itself and bring advantages to one of the Indian Ocean states by taking the lead in developing a multi-phase fisheries project in that state. It assessed the resource, formulated a development plan, and was well received by the Government. Some problems required solution; the Government insisted in 49% equity being held by the foreigner and 51% by the Government. The foreigner refused, on the grounds that government's objectives were primarily social and that the developing company was an economic institution. It required that the ultimate decisions be economic.

Another problem was the artificially high price of diesel fuel within the state. It was essential to the success of the enterprise, which was to sell its products in the world market, that it compete with goods and services priced at world levels. Although this point was ultimately recognized by the bureaucracy, the time taken to negotiate these and other minor points was so great that the developer, having spent large sums of its own funds and large blocks of its executive time, gave up and retired from the scene.

Jurisdictional rivalries — Some countries have a federal domain in which the central government has a fisheries development policy but the provincial authorities are primarily interested in protecting the indigenous fisherman. Thus the jurisdictional overlap and rivalry is a threat to a development and must be recognized.

Import and export duties — Many developing countries have, for good reasons, adopted a high level of direct economic control, which usually means stringent controls on imports, exports, and exchange. These are serious inhibitions to development because they induce delays in the industrial process and provide opportunities for petty harassment. If the riparian state is truly interested in a development policy it will make provision to abrogate the barriers for specific purpose, such as fisheries development.

Example — One nation somewhat outside the Indian Ocean area at present borders on anarchy, while its docks have been in that state for some years. Passing materials through customs is an art form of its own.

Foreign exchange controls — These can be among the most difficult of the mechanical details related to off-shore development, since the controls are invariably cloying and the time to transit the control apparatus for individual transactions is incredibly long. Also, a tightly controlled economy often leads to unrealistic foreign exchange rates, which can seriously damage a development enterprise. Furthermore, unrealistic foreign exchange rates often fluctuate unexpectedly. The nature of the rates and their control apparatus is a significant measure of the hospitality of the riparian state.

NATIONALISM

Extreme nationalistic policies can have the effect of discouraging all development based on outside capital, while indigenous capital is inadequate or is not interested. Hence there is no development of any sort.

Example — One state with a proven fish resource and demonstrable need for development has been attempting unsuccessfully for some years to achieve that development using domestic personnel and equipment. Off-shore developers are prepared to supply appropriate equipment, train personnel, and market the products, but the state has decreed that those developers will have only a small share of the benefits they generate. The result is that no off-shore developer has yet taken an active role. Economic nationalism has prevented development.

POLITICAL STABILITY

Although there is no such thing as absolute political stability, some of the states in the Indian Ocean littoral are somewhat mercurial and change within them tends to be violent.

Example — An enterprise set up in good faith and operating satisfactorily in an African state was halted when revolutionaries a couple of years ago threatened the management. The revolution was successful, the management left, and the enterprise ceased. The new regime now wishes the enterprise to be resumed, but so far the owners have been unwilling to return.

Example — Another firm in another country undertook, with its own resources, to initiate a survey to determine the feasibility of a project and to begin construction of a substantial capital-oriented development. When shooting started in the streets, the local employees cabled that they were leaving, abandoned their vessels, plant, equipment, and investment, and departed never to return. There is still no development in that state.

THE ETHOS

It is natural that some societies should have customs and accepted behavior patterns that are different from others. The rules of deportment at various points along the Indian Ocean littoral may differ in kind or in degree from those of the western world. In certain places nepotism, bribery, and gifts in kind to public officials are accepted as a part of the normal way of doing business. That is the unofficial milieu.

The official rules also vary from country to country. In some the governments are scrupulous about maintenance of obligations and the conduct of their affairs. In others this pattern does not obtain.

Example — One country invited a competent American concern to submit proposals for an integrated fishing, fish processing, and distribution system. At its own expense that company developed a complete integrated plan for viable operations, including secondary operations of some magnitude, which it submitted to the Government. The Government then turned the plan over to one of its friends for implementation. That friend was incompetent and the program failed.

THE NATURE OF PEOPLES

Indigenous fishermen are almost invariably a social problem. They are hereditary fishermen and have been for generations. Often they are on the lowest economic rung of society in the emerging country. Their incomes are low, their costs are low, their production is low, and they are characterized by little mobility, great individuality, a sense of independence, and no sense of discipline in an industrial context.

They usually have little mechanical aptitude but are often superb sailors, going great distances to sea in small, open boats. They are not creatures of change. Usually they are not suitable candidates for employment on industrial fishing vessels or in industrial fish processing plants. Furthermore, any capital-intensive processing operation predicated on the catching ability of indigenous fishermen using historic equipment is built on a foundation of sand. The operational range of those fishermen is short, their spirit of independence is high, their physical requirements are low, and their catch varies enormously in response to changes in the weather and movements of the fish.

Any capital-intensive fish processing operations must have a better catching arm than that offered by indigenous fishermen, using traditional equipment.

Example — In one country the USSR and the United States both have supported the construction of substantial shore processing facilities predicated on fish to be supplied by indigenous fishermen. Both operations failed, primarily from weakness of supply.

INDUSTRIOUSNESS OF THE CITIZENRY

This is a matter of importance only where the citizens are expected to play a technical or administrative fisheries role. It is important that the citizenry be capable of being organized and working in concert toward specified goals.

LEGAL STATUS OF FOREIGN INDUSTRIAL INSTITUTIONS

Many states for noneconomic reasons insist that foreign corporations hold only a minority position in any domestic fishing enterprise. This has two implications for the developer: financial—usually the developer is required to finance the enterprise at a ratio disproportionate to his share of return; control—ultimate control of the enterprise is in the hands of that sector least qualified to pass judgments on its operational aspects.

FINANCIAL ARRANGEMENTS

Repatriation of profits for those investing from outside is mandatory. Not only must the legal situation permit repatriation but there must be an assurance of availability of foreign exchange to satisfy the commitment.

Thus the institutional obstacles which can and usually do exist to some degree in developing states are serious factors, and the willingness of the state to modify, remove or overcome them is a measure of its hospitality.

ABSORPTION AND ALLOCATION OF CAPITAL

Some resourceful developing societies have produced fisheries programs in which the capital involved has been beyond the capacity of the society to absorb and beyond the sustaining capacity of the resource.

Example — One country (not of the Indian Ocean littoral) with an indicated resource and good initial catch rates and returns embarked on capital-spending which led to construction of far more vessels and plants than the resource could support. This overcapitalization soon became apparent and a painful withdrawal was effected. Losses were large.

The Indian Ocean region, except for shrimp and some tuna grounds, is virtually unexploited. The overcapitalization which has plagued most developed fisheries can be avoided by managing the stocks for maximum net economic, rather than biological, return.

The time to plan is now.

Availability of Funds

THE NEED FOR FUNDS

Funding requirements of a large fisheries project usually tend to be of the order of $5–$10 million. This represents a substantial proportion of the net worth of the world's largest fishing companies and few, if any, are prepared to risk that total amount in the difficult business milieu that characterizes most Indian Ocean states, although many will risk a portion.

Noteworthy too is the fact that the states with the greatest potential resources also have the greatest need of development and are least stable politically and economically. Few of these states have funds of their own for development, nor do the private citizens within them show any great desire to invest their hard-won capital in this field.

Example — One state recently had both foundations of its economy collapse almost simultaneously, not altogether of its own doing, then suffered a revolution and several subsequent coups d'état, and is therefore almost completely disrupted. It has no industrial or commercial potential. Its only potential resource is fish as agriculture, minerals, and oil are almost nonexistent.

No ordinary commercial institution can justify investing in that environment because of the political and economic instability. The state itself has no funds, and the citizens within the state have very few, certainly none available for any capital commitment within the country. Clearly then, in this case and others similar, funding can only flow from one of the established international institutions.

SOURCES OF FUNDS

The prime international sources of development funds are the International Bank for Reconstruction and Development (IBRD, the World Bank), the Asian Development Bank (ADB), and latterly the Kuwait Fund. Each lends money against the national guarantee of the recipient country. The repayment history is therefore good, regardless of the success or failure of the particular projects for which the funds are loaned.

HIDDEN VALUES

The hidden value of borrowing from such institutions under these conditions is that the national guarantee of the loan motivates the recipient country to ensure the success of the project. Furthermore, the country has a strong interest in future borrowings from the same institution and will wish to maintain its credit-worthiness. These factors are excellent insurance for the project and its developers against petty harrassment and bureaucratic tyranny. The shortcoming of borrowing from the international lending institutions is, especially with regard to IBRD, the fact that the institution is so large and its procedures so cumbersome that they do not fit the requirements of most fisheries developments very well.

Inspection missions, project preparation missions, appraisal missions, and review missions often follow one after another in slow succession, and in the end they often result in confusion in the institution and anger and frustration in the potential recipient country. Furthermore, in the case of entrepreneurial development, judgments are often subjective and banks are generally ill equipped to assess these. Purchasing procedures with a development bank loan are complicated and require specifications and bidding processes more in keeping with building a $200 million dam than a $5 million plant and boats.

An alternative approach, not so far tried to the best of the author's knowledge, is to consider the developer on his history of accomplishments and credit-worthiness rather than to try to evaluate the project, then to lend to the developer against the guarantee of the country. A condition of this ordinary commercial approach is that the developer should have sufficient equity committed to ensure his maximum effort. In short, the alternative is to lend to the developer rather than to the project.

Such an approach saves time, removes unnecessary procedural hurdles, and furthermore places the responsibility for performance squarely on the shoulders of the developer, where it belongs. It would enable the development, *ab initio*, of projects of the type that banks are ill equipped to appraise, since unit catch rates are, in advance of a commercial fishery, usually a matter of subjective opinion.

Example — There are two Indian Ocean states with overpowering economic and social needs and substantial underdeveloped stocks of readily harvestable fish within their national boundaries. There are at least two reputable, competent, international fishing companies that would undertake development and provide equity funds if one of the international agencies would provide debt funding. Few developers, however, are prepared to accept the delays and, to their minds, the unnecessary effort required to prove viability to the bank. They have confidence in their own judgment and this is demonstrated by their willingness to supply part of the required capital. Because of this impasse no development takes place.

Secondary Criteria

CREW AMENITIES

In its initial stages any larger development of the type envisioned here will require foreign personnel. Even though their pay rates and other associated costs are high, their performance will be unsatisfactory unless suitable provision is made for their human requirements of food, housing, entertainment and leisure time activities. Without them, regardless of pay and opportunities, qualified personnel will neither function well nor remain.

VESSEL SUPPORT FACILITIES

Since electric, electronic, hydraulic and mechanical support is necessary for almost any modern vessel, provision must be made for it. Furthermore, because the complexity and unitized nature of most components precludes the possibility of 100% back-up inventory, fast efficient communications and transport to back-up sources is desirable, preferably communications by telex, telephone, and direct air connection from Europe, Japan, or North America, or all three. Primary support can be built into a project almost anywhere, but secondary support is a matter of accessibility, and accessibility is the criterion.

FREIGHT CONNECTIONS AND HANDLING EFFICIENCY

These are significant for product removal and predictable supply requirements. They become an extraordinary cost element if loading facilities are unduly primitive (e.g. surf beach lightering), or distances are so long as to become very costly. Otherwise they are straight computable costs.

Tertiary Criteria

CRITICAL MASS

Although stock size must be sufficient to justify the commitment of initial effort and to support that effort for a reasonable period, and unit annual catch rates must be such as to produce a net unit cost at a level which will generate substantial contributions, it is nonetheless true that the entire project must be greater than a critical mass, i.e. it must be of sufficient magnitude at first or second inspection to justify the substantial efforts necessary to bring it to fruition. Development must be predicated on having room for expansion once initial viability is established.

MARKET DIMENSIONS

For the products mentioned above there is virtually no possibility of a single entrepreneur or production area setting or upsetting market prices. It is, however, possible that other species or products that would qualify under these various criteria might present an additional problem — that a new major source of supply could distort the current market structure and lead to unpredictably smaller returns. Sea urchins are a possible example.

COMPETITION

Fisheries are almost invariably a common property resource. Within limits, anyone can fish. If a developer fails, he fails for his own account and the account of his associates and backers. If he succeeds, on the other hand, he succeeds for everyone. Because of the common property nature of fisheries, emulators quickly appear; and despite the risk which the developer has taken, the reward he would earn if a private property resource were involved quickly becomes dissipated by the influx of competitors. Thus an innovator must take into account the competitive conditions which will obtain when his enterprise has been demonstrated to be viable.

Example — Indonesian policy provides specific protection for those who risk and succeed. Fishing rights are allocated in certain areas to those who have demonstrated viability by their industriousness, organization, and investment. The major attraction for developers is the prospect of continuing profits.

Ultimate Criteria

The ultimate criteria are the behavior of fish and the behavior of people. They are predictable in an environment where each has a historic behavioral pattern to form a basis for projection into the future. In an environment such as the Indian Ocean littoral, where there is little past history of behavior of either fish or people in the fisheries development context, any projection or plan is valid within only wide limits.

Furthermore, the abundance of fish is the most unpredictable of all natural resources and the most variable. Markets swing in relation to availability and demand shifts. Viability in fisheries development is therefore subject more to the luck of being in the right place at the right time than in most human activities.

Behavior and luck are relegated in this modest paper to the role of tertiary criteria because of imponderability, not unimportance.

Fishery Joint Ventures in Developing Countries[1]

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To an increasing degree joint ventures are being used to assist developing nations to make better use of the fishery resources in their own waters or adjacent thereof. Japan has been active in this field, providing technical assistance, equipment, training, and fellowships. The Japanese fishing industry has also provided capital and skills.

The first Japanese fisheries joint venture was established in 1953 and the system has grown rapidly since; by March 1972 there were 38 countries involved, with 77 enterprises and a capital investment of $25 million. Most joint ventures have been established in Asia and Oceania; Africa has shown the greatest increase in recent years. Most enterprises are for fishing activities, especially trawl fishing for shrimp; the others are for cold storage, fish processing, and aquaculture.

About 46% of joint venture enterprises are owned mostly by Japan, but increasingly the local country has an equal or larger share. Most land-based employees are of the local country, but over half the fishermen are Japanese; this reflects the difficulty of obtaining enough skilled local fishermen. One task of the ventures should be to train such men.

Successful joint ventures require the following: The national interest of the recipient country should be kept fully in mind; Recipient countries should take the steps necessary for resource conservation, for prevention of conflicts on the fishing grounds, and for avoiding excessive competition; Fisheries require complex infrastructures, including harbors and supply and storage facilities, which cannot be supplied by commercial enterprises. Arrangements should be made by the recipient country to provide these, by the government or through bilateral or multilateral assistance; and Recipient governments should fully appreciate the characteristics and risks of fishery ventures, and take a long view of development. They should recognize the need for exploratory and experimental fishing, and give favorable treatment regarding taxation, employment, import of fishing materials, and remittance of foreign exchange.

On a de plus en plus souvent recours à la formule des entreprises mixtes pour aider les nations en voie de développement à mieux exploiter leurs ressources halieutiques dans leurs eaux territoriales. Le Japon a joué un rôle actif dans ce domaine en fournissant une assistance technique, du matériel, une formation professionnelle et des bourses d'études. L'industrie halieutique japonaise a également offert des capitaux et des connaissances spécialisées.

La première entreprise mixte japonaise a été lancée en 1953 et, depuis, la formule a remporté un grand succès; en mars 1972, 38 pays l'avaient adoptée et ces entreprises étaient au nombre de 77, totalisant des investissements de 25 millions de dollars. C'est en Asie et en Océanie que ces entreprises ont été les plus nombreuses, tandis que l'Afrique a enregistré récemment le rythme d'augmentation le plus rapide. La plupart de ces entreprises concernent les activités de pêche, notamment la pêche des crevettes au chalut, les autres intéressant l'entreposage frigorifique, la transformation du poisson et l'aquaculture.

Dans environ 46% des cas, le Japon détient la quasi totalité des actions, mais de plus en plus les pays associés obtiennent une part égale ou plus importante. La plupart des employés à terre sont recrutés localement, mais plus de la moitié des pêcheurs sont japonais, ce qui illustre bien la difficulté qu'il y a à recruter sur place suffisamment de pêcheurs qualifiés; l'une des tâches des entreprises devrait être de former cette catégorie de personnel.

Le succès des entreprises mixtes dépend des conditions ci-après: Il faut garder constamment présent à l'esprit l'intérêt national du pays bénéficiaire; Les pays bénéficiaires doivent prendre les mesures nécessaires pour assurer la conservation des ressources, empêcher les conflits sur les lieux de pêche et éviter une concurrence excessive; Les pêcheries exigent des infrastructures complexes, notamment des ports, ainsi que des services de livraison et d'entreposage, qui ne peuvent être assurés par des entreprises commerciales. Des accords doivent être passés avec les pays bénéficiaires pour que ces services soient fournis soit par le gouvernement, soient dans le cadre d'une aide bilatérale ou multilatérale; et Les gouvernements bénéficiaires doivent connaître à fond les caractéristiques et les risques des entreprises halieutiques et envisager le développement

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dans une perspective à long terme. Ils doivent admettre la nécessité de la pêche exploratoire et expérimentale et accorder des traitements de faveur en ce qui concerne les taxes, l'emploi, les importations de matériel de pêche et le versement de devises.

Cada vez es más frecuente la creación de empresas conjuntas para ayudar a los países en desarrollo a aprovechar mejor los recursos pesqueros de sus aguas. Japón ha trabajado en este sector, facilitando asistencia técnica, equipo, capacitación y becas. La industria pesquera japonesa ha facilitado además capital y personal especializado.

La primera empresa conjunta japonesa se creó en 1953, y el sistema ha proliferado rápidamente desde entonces; en marzo de 1972 los países implicados eran 38, con 77 empresas y una inversión de 25 millones de dólares EE.UU. La mayoría de estas empresas conjuntas radican en Asia y Oceanía; el mayor índice de aumento en los últimos años se ha registrado en Africa. En su mayoría se trata de actividades pesqueras, especialmente pesca de arrastre de camarón; el resto son frigoríficos, elaboración de pescado y acuicultura.

En un 46% de los casos, aproximadamente, estas empresas conjuntas son predominantemente de propiedad japonesa, pero aumenta el número de países participantes con igual o mayor número de acciones. La mayoría de los empleados que trabajan en tierra proceden del país en cuestión; en cambio, más de la mitad de los pescadores son japoneses, debido a la difficultad de obtenerlos en el país suficientemente preparados. Una de las tareas de estas empresas debe ser precisamente ésta: preparar pescadores.

Para que estas empresas conjuntas tengan éxito es necesario: Tener constantemente presente el interés nacional del país beneficiario; Que los países beneficiarios tomen las medidas necesarias para conservar los recursos, impedir conflictos en los caladeros y evitar un exceso de competencia; La pesca requiere una infraestructura compleja, incluidos puertos, medios de suministro y almacenes, que las empresas comerciales no pueden aportar. El gobierno del país beneficiario debe tomar las medidas necesarias para facilitar esta infraestructura, bien directamente o mediante asistencia bilateral o multilateral; Los gobiernos eneficiarios deben ser claramente conscientes de las características y riesgos de las actividades pesqueras, y pensar en el desarrollo a largo plazo. Deben reconocer la necesidad de las actividades de pesca exploratoria y experimental y aplicar un tratamiento de favor por lo que se refiere a impuestos, empleo, importación de material pesquero y envío de divisas.

In recent years international collaboration in development of marine resources has increased. Several nations, including Japan, conduct fisheries both in their immediate waters and far out in the oceans. On the other hand, the majority of the developing countries still lack technical knowhow and capital to develop an industry to exploit even the resources existing in their territorial waters. Increasing numbers of these countries have started to promote fisheries as an economic development measure. It is important for developed countries and competent international organizations to help them to obtain the necessary capital and skill to do this. Japan, under its bilateral program, has been providing technical assistance, equipment, training, and fellowships. Its industry has provided capital and skills through joint ventures. Activities in this field are expanding rapidly.

The joint venture is one of the most efficient, quick, and effective means of developing industrial fisheries in developing countries. It can provide quickly in one package all the elements necessary for fishing development — capital, equipment, skill, and employment for local population — and provide foreign exchange by exporting the products.

On the other hand, since joint ventures are set up as commercial operations, there is a limit to investment on infrastructure, such as fishing ports, roads, marketing facilities, and training schools, and since fisheries are risky ventures to start with, many joint ventures have failed because of unexpected difficulties. It is therefore considered essential that recipient countries must assist in the solution of problems which cannot be solved on a commercial basis.

Development of Japanese Overseas Fisheries Joint Ventures

Since the first joint venture enterprise was established in 1953, Japanese overseas fisheries joint ventures have developed steadily. This activity has shown a remarkable degree of expansion since 1966, when the economic situation in Japan became stabilized and the status of holding foreign currency improved. Reflecting the domestic and overseas situations, joint ventures should continue to develop in the future.

BACKGROUND

Japan is an island country surrounded by the sea, and fish products have always formed a large proportion of the diet of the population. The demand for fish products in Japan has increased in recent years, the yearly per capita consumption in 1969 showing a 26% rise over the 1964 level. The total expenditure per household in 1969 was 1.6 times in urban areas and 1.9 times in rural areas more than the 1964 levels. Currently 53% of the yearly per capita intake of protein comes from fish products. Import of fishery products in 1970 was $318 million, three times that of 1965, but increases in catch and imports cannot meet the growing demand. Prices have steadily risen, and costs of medium and high-class fishes (tuna, shrimp, octopus, and seabream, etc.) are expected to go up still further. Furthermore, the Japanese people demand particular kinds of fish, and high quality, as well as a stabilized supply.

To help supply this demand, Japan cooperates with countries having potentially large fish stocks which they are unable to exploit. Japan imports the resulting products in large quantities and gives financial assistance to the countries whose stocks are to be exploited.

Shrimp, skipjack, and other products, the demand for which is steadily increasing in Japan and international markets, are being caught in large quantities in various countries. In the case of the skipjack pole-and-line fishery, which requires live bait fish to be caught in the coastal area of the country, live bait fishing is conducted in the near-shore or territorial waters of coastal countries. Also, in the case of particular coastal fishes, fishing in the near-shore waters or territorial waters is involved.

An increase of restrictions in the development of the domestic fishing industry in Japan, the tendency to develop overseas economic cooperation due to the growth of Japanese economy, and increased holdings of foreign currency are other stimuli for activity in this sphere.

PRESENT STATUS OF OVERSEAS JOINT VENTURE FISHERIES

Overseas fishery joint ventures by Japanese enterprises, including fish processing, cold storage, and aquaculture, have increased since 1953 when the first joint venture was established (Table 1). As of March 1972, 31 developing countries were involved with 56 enterprises and invested capital of nearly $20 million, 73% of the enterprises and 80% of the investment. The increase in the African region was remarkable in these years.

TABLE 1. Authorized investment by region, March 1972.

Region	No. of countries	No. of enterprises	Authorized capital (in $'000)	Total investment by Japan (in $'000)
Central and South America	8	15	9,458	7,277
Asia and Oceania	15	37	16,641	12,163
Africa	11	13	4,296	2,251
Europe	2	2	2,559	984
North America	2	10	4,099	2,381
Total	38	77	37,053	25,056

TABLE 2. Enterprises by region and kind of operation. Figures in parentheses indicate shrimp trawling.

Region	Trawl fishing	Skipjack tuna fishing	Other fishing	Subtotal (Fishing)	Aquaculture	Cold storage	Fish processing	Others	Total
Central and South America	5(2)	1	4	10(2)	–	2	2	1	15
Asia and Oceania	17(14)	3	–	20(14)	7	8	2	–	37
Africa	6(5)	1	1	8(5)	–	4	1	–	13
Europe	–	1	–	1	–	–	1	–	2
North America	–	–	2	2	1	–	6	1	10
TOTAL	28(21)	6	7	41(21)	8	14	12	2	77

The types and numbers of businesses in operation (Table 2) show that fishing leads cold storage, fish processing, and aquaculture (eel, shrimp, pearl, etc.) Trawl fishing (including shrimp) accounts for 68% of the fishing business. Due to increased demand for shrimp and skipjack in world markets and in Japan and consequent urgent requests for their exploitation, fishing, and cold storage operations for these species have increased remarkably.

About 46% of joint venture enterprises are those in which Japan shares more than 50% of the investment; Japan holds 100% of the investment in about half of these. Some countries request that the share of stock by the home country should rise to 50% within a stated period (about 10 years). In 21% of the enterprises the share is half and half by Japan and the home country, and local government (including semi-governmental corporation) investment is increasing.

According to reports made by the industries concerned, the number of local employees working for the enterprises in 1970 amount to 94% of the total employees in the land sector and 49% in the sea sector. The smaller percentage in the latter seems to be based on the characteristics of fishing, which requires intensive labor at sea and long voyages. It is often difficult to obtain adequate local labor on account of differences in social customs.

In 1970, 40% of joint venture enterprises showed profits. These were mostly the cold storage businesses (including purchase and import of fish products), and fish processing. A smaller proportion (35% of fishing enterprises had profits in the same year, compared with 60% of joint ventures in manufacturing.

The fact that several enterprises were forced to suspend business indicates the difficulties faced in overseas fishery joint venture management.

Problems and Difficulties of Fisheries Joint Ventures

The following are the main problems involved in fisheries joint ventures:

NATURAL FACTORS

Fishing depends greatly on natural factors such as weather, oceanographic conditions, and fish resources. There have been instances where ventures became unprofitable and were discontinued because of unexpected fluctuations of the catch caused by natural conditions. In view of this, a full prior investigation is most important when new resources are to be exploited. Normally, at least 2 or 3 years of exploratory and experimental fishing are required to ascertain the size of the exploitable resources, and the suitable types of fishing vessels, gear, equipment, and methods.

LAND FACILITIES

Various land facilities, including harbors, supply stores, boat repair facilities, and fish storage, are indispensable, and their lack greatly limits fishing operations. In the absence of these facilities, cold storage and freezing vessels must be used, and they add a considerable financial burden to an enterprise.

RESOURCE CONSERVATION AND EXCESSIVE COMPETITION

Excessive competition for fishing grounds often arises between traditional fisheries and new ventures, or in newly developing ventures which are overcapitalized. This causes conflicts and limits fishing operations. Too rapid an increase of the number of enterprises should thus be avoided to ensure proper management of the fish resources.

EMPLOYMENT AND TRAINING OF TECHNICAL PERSONNEL

Many foreign countries limit the employment of foreign personnel, including the length of their stay in the country, and make it a condition for joint ventures that a certain number of local people be employed. However, it is often the case that there are few local people who have knowledge, skill and experience of modern fisheries to fill the posts. Where there is no sea-going tradition in a country, it is often virtually impossible at the initial stage of joint ventures to employ local people for the crews, and the low productivity of the local labor often jeopardizes the enterprise. There is a need for the developing countries to recognize the special characteristics of fisheries and to make their employment policies flexible. At the same time, provision should be made for the training of local personnel.

IMPROVEMENT OF MARKETING STRUCTURE AND INCREASE OF FISH CONSUMPTION

In developing countries the marketing structure is usually inadequate, and there is not sufficient demand for fish; fish production is therefore intended mostly for export. However, the exportable species of fish are limited, and demand is affected by international market conditions. In most countries, there is a need to increase domestic fish consumption, and to reorganize and improve the marketing and distribution structure from landing to retailing, including transport, storage, and sales facilities.

GENERAL PROBLEMS

Besides the above-mentioned difficulties, which are characteristic of fisheries, the following general problems might be mentioned: there are instances where remittance of export income, loan repayments, or income of foreign technical personnel is restricted; restrictions are often imposed on importation of materials such as fishing vessels, gear, equipment, and spare parts, or high import duties are imposed on them; administrative procedures are often complex and slow.

Future of Joint Ventures in Fisheries

Fishery joint ventures benefit developing countries by providing capital, technology, and management experience, and thus are an effective form of international economic cooperation. These ventures also contribute to the development of new fish resources for human consumption, industrial use and export, increase employment, and stimulate the development of related industries. At the same time, joint ventures benefit the investing country since they can ensure a reliable supply of fishery products. From the viewpoint of the world economy, joint ventures contribute to efficient division of labor and facilitate a balanced development of national economies.

However, recipient countries often forget that joint venture investment is made on a commercial basis with a profit motive, and they may expect too much too soon. In their haste to obtain results, misunderstandings can arise which prevent successful development of the enterprise. The following points are essential for successful joint ventures:

The national interests of recipient countries should be fully taken into account. Apart from the commercial interest, the joint venture should contribute to the economic development of the recipient country, e.g. by ploughing back profits, by creating related industries, and by assisting in vocational training. Mutual understanding and confidence are indispensable.

The recipient countries should take the steps necessary for resource conservation, for prevention of operational conflicts in fishing grounds, and for avoiding excessive competition of enterprises. The Japanese Government encourages economic cooperation and joint ventures, but it has taken measures to check such investment whenever it is considered to affect resource conservation adversely, to contravene international agreements, or to cause excessive competition or operational conflicts.

Fisheries require a complex infrastructure, including harbors and supply and storage facilities, which cannot be provided by commercial enterprises. These facilities, as well as vocational training, should therefore be provided largely by governmental, bilateral, or multilateral assistance. If this is arranged, the risks and financial burdens of joint enterprises are reduced. Thus for joint ventures to be successful, governmental and international assistance should be integrated with private investment.

Recipient countries should fully appreciate the characteristics and risks of fisheries joint ventures and take a long-term view of fishery development. They should recognize the need for exploratory and experimental fishing, and support joint ventures by giving favorable treatment regarding taxation, employment, import of fishing materials, and remittance of foreign exchange.

Fishery Development and Management in Thailand[1, 2]

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TIEWS, K. 1973. Fishery development and management in Thailand. J. Fish. Res. Board Can. 30: 2333–2334.

After a period of stabilization lasting more than 20 years, the Thai sea fisheries developed rapidly during the past decade through the introduction of trawl fishing. Suitable nets and fishing techniques were demonstrated and introduced in the course of a German bilateral aid project. This new input, together with a high level of technical abilities among the fishermen, the availability of sufficient capital to finance a trawler fleet of more than 2,500 boats, and adequate support from the Thai Government, resulted in rapid development of trawling from small vessels. Landings were about 600,000 metric tons of groundfish from the coastal area in 1970. About half of this is for human consumption, the remainder mostly being used fresh for duck food or, after processing, as chicken food. The level of development achieved has unfortunately meant that the moderately rich bottom-fish resources of the Gulf of Thailand have become overexploited. In 1971 the catch per unit of effort had decreased to only a quarter of the original, making trawling operations only marginally economic. This points up the difficult problem of the control of fishing effort, which the Government of Thailand, no less than other nations, has not yet been able to resolve satisfactorily.

Après une période de stagnation de plus de 20 ans, les pêcheries maritimes de la Thaïlande ont pris un rapide essor au cours de la dernière décennie grâce à l'introduction de la pêche au chalut. Des filets et des techniques de pêche modernes ont fait l'objet de démonstrations et ont été adoptées dans le cadre d'un projet allemand d'aide bilatérale. Cette contribution, joint à un niveau élevé de compétence technique parmi les pêcheurs, à la disponibilité de capitaux suffisants pour financer une flottille de plus de 2,500 chalutiers et à l'appui dynamique du Gouvernement thaïlandais, a abouti à un rapide essor du petit chalutage. Les quantités débarquées ont atteint approximativement 600,000 tonnes métriques de poisson de fond pour la zone côtière en 1970. La moitié environ est destinée à la consommation humaine, le reste étant essentiellement utilisé à l'état frais pour l'alimentation des canards ou, après traitement, pour l'alimentation des poulets. Un tel stade de développement signifie malheureusement que les ressources médiocres en poissons de fond du golfe du Siam sont surexploitées. En 1971, les prises par unité d'effort sont tombées à un quart seulement de ce qu'elles étaient à l'origine, les opérations de chalutage se trouvant ainsi n'avoir plus qu'une importance économique marginale. Cela tend à démontrer combien il est difficile de contrôler l'effort de pêche — difficulté que le Gouvernement de la Thaïlande, pas plus que d'autres nations, n'a été en mesure de résoudre de façon satisfaisante.

Después de un período de estabilidad que ha durado más de 20 años, en Tailandia, la pesca oceánica ha aumentado rápidamente durante el pasado decenio con la iniciación de la pesca de arrastre. En el curso de un proyecto alemán de ayuda bilateral se hicieron demostraciones de redes y de téchnicas de pesca, que más adelante se llevaron a la práctica. Estas innovaciones, junto con una mayor capacidad técnica de los pescadores, disponibilidad de capital suficiente para financiar una flota de arrastreros compuesta por más de 2500 embarcaciones y la ayuda por parte del Gobierno de Tailandia, dió por resultado un rápido incremento de la pesca de arrastre realizada con barcos pequeños. En 1970 se descargaron unos 600,000 toneladas métricas de especies demersales costeras. La mitad de esta cantidad se destina al consumo humano y el resto se emplea principalmente en fresco para la alimentación de patos o, después de tratado, como pienso para aves de corral. Desgraciadamente el perfeccionamiento logrado ha significado que los recursos demersales del Golfo de Tailandia, que eran moderadamente ricos, hayan sido superexplotados. En 1971 las capturas por unidad de esfuerzo habían disminuido a sólo un tercio de las originales, por lo que la explotación con arrastreros constituía una actividad de poca importancia económica. Ello demuestra lo difícil de reglamentar la intensidad de la pesca que el Gobierno de Tailandia, como sucede con otras naciones, aún no ha podido resolver satisfactoriamente.

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

[2] The complete text of this paper is being published in English in Arch. Fischereiwiss. 24 (1–3): 271–300, 1973. A condensation by the author is given here.

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Author's Condensation

THAILAND, covering about 514,000 km^2 and with a population of about 35 million, is located between 6° and 20°N in a zone of tropical monsoon climate with water temperatures around 28 C. The country has experienced one of the most exciting fisheries developments in the world during the past decade, after its relatively modest fisheries landings had stagnated for more than 20 years prior to 1960. According to the FAO fisheries statistics, its marine fisheries production has risen from about 150,000 metric tons in 1960 to about 1.5 million tons in 1970. Though the reliability of these estimates of production is questionable, there is no doubt that the Thai fishery has increased tremendously during the past decade.

This paper documents the German Technical Aid to Thailand in the field of fisheries provided since 1961, which has had a great influence on fishery development. The paper describes the status of the Thai fishery prior to 1960, measures taken for its development, the bottom-fish stocks, the development of the fishery since 1960, the necessity for regulation in the trawl fishery, and the problems that exist in formulating regulation measures. A series of conclusions is given, which arise from the example of the Thai trawl fishery and which are of general interest.

The rapid development of the Thai fishery was possible, not only because fishermen did show sufficient technical understanding to utilize a fishing method until then unknown to them, but also because Thailand had sufficient capital to finance a trawler fleet of more than 2500 vessels. After the introduction of the trawl fishery, which had been adapted to Thai conditions and was carried out in the course of the German Technical Aid project, fishery development was so rapid that overexploitation of the bottom-fish resources in the Gulf of Thailand was unavoidable. Regulation measures proposed for the prevention of such overexploitation could not be realized, for several reasons. The main problems of a scientifically sound regulation program of the Thai trawl fishery are: lack of reliable catch statistics, partly due to the fact that taxonomic determination is often extremely difficult for the 200–300 fish species involved; lack of adequate biological data concerning the species utilized; and difficulties in respect to age determination and tagging of almost all fish species. A further problem consists, in general, of the political difficulties in enforcement of regulation measures.

The only reliable data that permit a description of the changes in the bottom-fish resources, which occurred in the course of the fishery development, were collected by the research cutter *Pramong 2* under the German Technical Aid fisheries project. According to these data, a decrease of the catch/hour occurred from 249 kg in 1963 to 66 kg in 1971, and in some subareas it even went down to 33 kg. On the basis of these data and of an estimate by the Thai Fisheries Department of the size of the fleet, the Thai landings of bottom fish in 1970 were thought to amount to 766,000 tons as a maximum. However, the landings probably did not amount to more than 600,000 tons. The landings as given in the Thai catch statistics, i.e. 945,000 tons, must be considered an overestimate. The drastic decrease in the catches per unit of effort is alarming and requires not only a complete cessation of trawler building, but also a reduction of the present trawler fleet by at least one-third.

The most striking observation in Thai fishery development is perhaps that it was possible at all, without carrying out at the same time any sophisticated training programs for Thai fishermen. Training by demonstration, occupying only 2–3 days, took place in the Thai fishing villages. In the light of these experiences, it seems desirable to examine critically some at least of the expensive fishery training programs in developing countries.

The Thai trawl fisheries development is a good example of a straightforward program based on a balanced concept. First a suitable bottom trawl was developed. Immediately afterwards a systematic survey of the bottom-fish resources was carried out, and at the same time information on them was given to fishermen in the villages. Because a standard fishing gear was used from the beginning, a reliable picture was obtained of changes in the fish resources that occurred as a consequence of fishery development. Research activities directed to this end will also be indispensable in future, because they supply the only reliable data concerning the status of the resources, and also permit control of fishery statistics. The Thai example has, however, shown that fishery administration in developing countries should pay far more attention to catch statistics than has been the practice, because without reliable statistics the regulation of stocks is almost impossible. It is recommended that the Fishery Department of FAO intensify its advisory activities in this field.

In 1972, for an initial 3 years, a partnership agreement between the Bundesforschungsanstalt für Fischerei, Hamburg, and the Marine Fisheries Laboratory, Bangkok, was established as a continuation of Technical Aid in the field of fisheries that has been in effect since 1961. Under this agreement, advice will in future also be given in the fields of aquaculture, marine pollution, taxonomy, and the development of fishing gear, among other things. In this connection it will be possible to send to Thailand for a few weeks, experts who are not available for long-term assignments. It is hoped that this new form of development aid will set an example for similar agreements by fishery research institutes of other countries, because important new prospects can be expected from it in respect to fishery development, management, and research.

Fisheries Development and Management in Indonesia[1]

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Zachman, N. 1973. Fisheries development and management in Indonesia. J. Fish. Res. Board Can. 30: 2335–2340.

Before 1968, fishery development in Indonesia concentrated on the artisanal fisheries. No significant progress was made until the emphasis changed to the commercial fisheries, as part of the first 5-year development plan of 1969–74. The new approach was on economics and marketing instead of on production. A long-term plan over 25 years has been prepared, divided into 5-year operational plans.

Indonesia has important fishery resources, especially pelagic stocks. Large extents of continental shelves also provide the possibility of increased trawl fishing, especially for shrimp. Conditions are also favorable for aquaculture. The position of the country between two oceans and two continents locates it favorably to exploit the tunas of both the Indian Ocean and the Pacific Ocean, and to maintain a flow of fishery products to international markets. Manpower is abundant and relatively cheap.

The program to develop artisanal fisheries concentrates on increasing the income per capita of fishermen through developing fish marketing and production. Commercial fisheries are concentrating on production of export products, especially shrimp, skipjack, and tuna, to earn foreign exchange. Effective and efficient administration is being formed to carry out fisheries development, involving the reorganization of the Central and Regional Fisheries agencies. Staff are being upgraded, training and education are being reviewed, and research is being intensified.

New laws have resulted in the establishment of eight domestic companies with a total investment of $27 million (US). Exports of fishery products have significantly increased, especially shrimp. Marketing is improved through the establishment of a cold chain, which is expected to lead to improved quality of products and increased earnings for fishermen.

The goals of the first 5-year plan include: establishment of large-scale fishing industries, to export products valued at $30–40 million (US) per year; establishment of marketing facilities for fresh fish distribution in the most populated areas; raising artisanal fisheries to a level where they can independently sustain growth; establishment of an effective research system; establishment of an effective education and training system; establishment of fisheries cooperatives; improvement of the administration of fisheries.

Avant 1968, le développement des pêches en Indonésie portait surtout sur les pêches artisanales. Aucun progrès sensible ne fut accompli jusqu'à l'on mit l'accent sur la pêche industrielle, dans le cadre d'un premier plan quinquennal de développement portant sur la période 1969–74. La nouvelle approche a donné la primauté à l'économie et à la commercialisation par rapport à la production. On a préparé un plan à long terme de 25 ans subdivisé en cinq plans opérationnels de cinq ans.

L'Indonésie a d'importantes ressources en poisson, notamment en ce qui concerne les stocks pélagiques. L'ampleur du plateau continental donne aussi la possibilité d'intensifier le chalutage, en particulier pour pratiquer la pêche crevettière. Les conditions sont également favorables à l'aquiculture. Situé entre deux océans et deux continents, le pays est bien placé pour exploiter les thons de l'océan Indien comme ceux de l'océan Pacifique et pour assurer un écoulement régulier de produits de la pêche sur les marchés internationaux. La main-d'oeuvre est abondante et relativement bon marché.

Le programme visant à développer les pêcheries artisanales a surtout pour objet d'augmenter le revenu individuel des pêcheurs en stimulant la production et la commercialisation du poisson. Les pêches industrielles se concentrent sur la production de produits d'exportation, notamment les crevettes, la bonite à ventre rayé et le thon, pour obtenir des gains de devises. La mise en place d'une structure administrative solide et efficace doit servir de base au développement halieutique, notamment par la réorganisation des organismes centraux et régionaux des pêches. La fonction est revalorisée, la formation et l'enseignement sont soumis à un nouvel examen et la recherche est intensifiée.

Une législation nouvelle a abouti à la création de huit sociétés nationales dotées au total d'un capital de 27 millions de dollars E.-U. Les exportations de produits de la pêche ont augmenté sensiblement, notamment

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

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en ce qui concerne les crevettes. La commercialisation a bénéficié de l'établissement d'une chaîne du froid qui devrait permettre d'améliorer la qualité des produits et assurer des gains supplémentaires aux pêcheurs.

Le premier plan quinquennal a entre autres les buts suivants: établir des industries de la pêche assez importantes pour exporter des produits représentant une valeur de 30 à 40 millions de dollars E.-U. par an; créer des moyens de commercialisation permettant la distribution du poisson frais dans les zones les plus peuplées; porter les pêches artisanales à un niveau tel qu'elles puissent ensuite assurer leur propre expansion; mettre sur pied un système de recherche efficace; établir un système d'enseignement et de formation efficace; créer des coopératives de pêcheurs; améliorer l'administration des pêches.

Hasta 1968, el desarrollo pesquero de Indonesia se concentraba en torno a las pesquerías artesanales. No se logró ningún progreso importante hasta que en el primer plan quinquenal de desarrollo 1969–74, que se orientó hacia la economía y la comercialización en vez de hacia la producción, se empezó a insistir en las pesquerías industriales. Se ha preparado un plan a largo plazo, para más de 25 años, dividido en planes operativos quinquenales.

Indonesia cuenta con recursos pesqueros importantes, especialmente pelágicos. La gran amplitud de la plataforma continental ofrece además la posibilidad de aumentar la pesca al arrastre, especialmente de camarones. Las condiciones son también favorables para la acuicultura. La situación del país, entre dos océanos y dos contienentes, le da una posición favorable para explotar las poblaciones de túnidos del Indico y del Pacífico y para abastecer continuamente de productos pesqueros a los mercados internacionales. La mano de obra es abundante y relativamente barata.

El programa de desarrollo de las pesquerías artesanales aspira a aumentar los ingresos por persona de los pescadores, mejorando el mercadeo y la producción de pescado. Las pesquerías industriales se concentran en la producción de productos de exportación, especialmente camarón, listado y atún, para adquirir divisas. Se está organizando un sistema administrativo eficiente y eficaz, que se encargue del desarrollo del sector pesquero, con la consiguiente reorganización de los organismos pesqueros centrales y regionales. Se está mejorando la preparación del personal, examinando los sistemas de capacitación y enseñanza e intensificando la investigación.

Gracias a nuevas leyes se han craedo ocho compañías nacionales, con una inversión total de 27 millones de dólares EE.UU. Las exportaciones de productos pesqueros han aumentado notablemente, especialmente las de camarones. La comercialización ha mejorado gracias al establecimiento de una cadena de frío, que se espera permita mejorar la calidad de los productos y aumentar los beneficios de los pescadores.

Entre los objetivos del primer plan quinquenal pueden citarse:
el establecimiento de industrias pesqueras a gran escala, para exportar productos por un valor anual de 30–40 millones de dólares EE.UU.; el establecimiento de instalaciones de comercialización para la distribución de pescado fresco a las zonas más populosas; la mejora de las pesquerías artesanales hasta el punto en que puedan desarrollarse autónomamente; el establecimiento de un sistema eficaz de investigación; el establecimiento de un sistema eficaz de enseñanza y capacitación; la creación de cooperativas pesqueras; la mejora de la administración del sector pesquero.

The history of fisheries development in Indonesia can be divided into two phases — development prior to 1968, and after that date. The main characteristic of activities before 1968 was that priority had been given to development of the artisanal fisheries, while the possibilities of developing commercial fisheries had been neglected. But because of unstable conditions in national politics and economics and the complexity of problems related to the artisanal fisheries, no significant progress was made. The role of fisheries in supporting national economic development remained insignificant, and there was even a declining trend.

At that time fisheries products were bulk commodities, mainly consisting of traditionally processed fish — dried/salted and other cured products — the quality being far below international standards. From the nutritional point of view these commodities did not contribute much to improvement of the people's diet. Another important aspect was that such processing did not require high-quality raw material, which in turn did not stimulate the producers (i.e. small fishermen) to develop improved methods of fishing and handling the catch. Although there was great disparity between wholesale and retail prices for fishery products, the existence of a monopolistic trade dominated by a small group of capital owners caused an improper distribution of profit, mostly to the benefit of the trade sector. The fishermen's average income remained low and with their backward attitude these had become the main sources of development problems.

The development phase after 1968 started with adoption of a new policy and strategy in fisheries as a preparation for the first 5-year development plan (1969–74). Its main characteristic was an economic and marketing approach, rather than a production approach, as fish production cannot be separated from the marketing aspect and fisheries must be considered a commercial business activity. Development strategy is based on creation of a favorable climate, which enables economic forces to exploit fishery resources at a level sufficiently high to achieve targets valuable to development of the national economy — foreign exchange earnings, increased GNP, and a supply of food to fill the nutrition gap.

In developing the economic forces, the role of government is first to identify the possibilities of exploitation of resources matched with the marketing outlook for fishery products abroad as well as domestically, with the aim of making fisheries attractive for capital investment. As a second step, preinvestment activities must be conducted by the government in the form of research and surveys, feasibility studies, training of personnel, and development of needed infrastructural projects such as landing and storage facilities, also marketing and distribution facilities. By these actions it is hoped that there will be a spontaneous and dynamic growth of economic activities leading toward a rational utilization of the fishery resources over a long period of time.

To secure effective and efficient development, sound planning and programming is a necessity. A long-term plan over a period of 25 years is prepared, and is divided into short-term operational plans, each of 5 years duration.

Fisheries Development and management in Indonesia

Development in its general meaning is growth toward progress. From the government's point of view management in fisheries means developing a system of exploitation of resources by the private sector (industrial and artisanal fisheries), in order to achieve goals already determined in its planning, and to do this without damaging the resources.

The motivation for development is based on the existence of prospects. In terms of fisheries, these prospects are biological resources, geography, and manpower.

BIOLOGICAL RESOURCES

Indonesia has considerable fisheries resources (Tables 1 and 2), a consequence of favorable climatic and hydrographic conditions. If these are properly developed they will not only meet the domestic fish requirements of the people, but might also provide a surplus for export. Some parts of Indonesian waters, such as those offshore with high pelagic resource potentialities, are still practically unexploited, and substantial harvests can be anticipated. The main pelagic resources include surface tunas like the skipjack, mackerel like fishes, clupeids, round scads, and squids. In addition Indonesia is located in and surrounded by two oceans where concentrations of deep-swimming big tunas are found.

TABLE 1. Estimation of fisheries resource potentials as given in the Master Plan of Fisheries Development.

Community	Metric tons (%)
Shrimps	
Marine	125,000 (1.6)
Brackish water	82,000 (1.0)
Skipjack	150,000 (1.8)
Tunas	50,000 (0.6)
Other pelagic fishes	4,000,000(49.1)
Demersal fishes	3,000,000(36.3)
Milkfish	360,000 (4.4)
Eels	34,000 (0.4)
Frogs	75,000 (0.9)
Freshwater fish	270,000 (3.3)
Ornamental (No. of fish)	30,000,000

TABLE 2. Indonesian fish production (metric tons) 1960–72.

	Culture					Capture			
	Fresh water	Paddy fields	Brackish water	Other	Sub total	Inland waters	Marine	Sub total	Total
1960	39,801	14,169	43,078	–	97,048	249,674	410,043	659,717	756,765
1961	36,585	17,703	32,807	–	87,095	297,988	525,198	823,186	910,281
1962	39,925	16,232	32,704	–	88,861	281,449	537,983	819,432	908,293
1963	41,580	16,140	39,239	–	96,959	279,165	558,970	838,135	935,094
1964	66,517	21,049	42,421	7	129,994	272,860	590,000	862,860	992,854
1965	63,302	24,227	53,413	279	141,221	296,007	665,107	961,114	1,102,335
1966	59,938	19,895	54,067	10	134,001	347,591	720,236	1,067,827	1,210,828
1967	60,230	20,540	56,750	106	137,626	364,875	677,933	1,042,808	1,180,434
1968	53,348	19,083	43,528	160	116,119	320,409	722,511	1,042,920	1,159,039
1969	42,179	20,224	51,876	573	114,854	314,201	785,344	1,099,545	1,214,399
1970	51,345	24,223	55,908	3,126	134,602	286,519	807,391	1,093,910	1,228,512
1971	54,647	22,540	60,788	388	138,363	285,745	820,447	1,106,192	1,244,555
1972[a]	55,320	22,750	61,400	390	139,860	289,440	838,475	1,127,915	1,267,775

[a] Preliminary data.

The availability of huge continental shelves, the Sunda shelf at the western part and the Sahul shelf at the eastern part of the Indonesian Archipelago, make increased demersal fishing possible. A large part of the shelf area within the 10-mile limit consists of good trawling grounds. Shrimps are the most important resource here. From the beginning of this fishing activity, steps must be taken for management of the resources.

The reef region is another that possesses fish resources. Several reef species of importance, such as *Caesio* *erythrogaster* and *C. pisang*, have been observed in abundance, and there is also an indication of the availability of snappers (lutianids) along the slope lines.

Rainfall throughout the year and an abundant water supply have made it possible for Indonesia to cultivate fish. Diverse water conditions support many systems of fish culture, in fresh and brackish ponds, in rice fields, and in lakes and streams. A remarkable increase in yield could be obtained from potential areas, consisting of several hundred thousand hectares of well-irrigated rice fields, and reclaimed land from mangrove swamps.

Indonesian mariculture is negligible at present but this sector is anticipated to be developed in the near future. The presence of suitable bays, inlets and other enclosed areas offers good prospect for this development.

Geography

Indonesia is an archipelago in the tropical region. Its posistion between two continents and two oceans gives the following advantages:

It is well located to exploit tunas both in the Indian Ocean and the Pacific Ocean. Because of the relatively short distance to these grounds in comparison with other fishing countries, Indonesia will be able to keep fishing costs low and increase the frequency of fishing trips, both important aspects.

It is strategically located in the middle of the international net of sea-traffic, giving a good opportunity to maintain a flow of exports of fishery products.

Manpower

Indonesia is a highly populated country, with approximately 120 million people in 1971. The scarcity of job opportunities produces an abundance of labor, and the relatively low level of wages helps keep production costs low.

Fisheries Development Programs

In developing the fisheries three main programs have been undertaken: development of artisanal fisheries; development of commercial fisheries; improvement of government fisheries services.

Development of Artisanal Fisheries

A careful examination of problems related to artisanal fisheries has led to the conclusion that the main reason for their backward status is the low income of fishermen and lack of entrepreneurship. This has prevented any sustained growth.

The objective of development here is, therefore, to increase the income per capita and to stimulate the training of entrepreneurs.

This program consists of two phases: development of fish marketing, and development of fish production.

The fish marketing development program has the objective of creating a well-organized fresh fish marketing system, especially in densely populated regions. A cold chain will maintain the freshness of the fish from catching to retailing. This will bring a more continuous supply of fish to the consumer, and together with the improved quality attained will induce fish consumption and stimulate increased production. This will encourage producers to conduct more selective fishing and to improve their handling methods.

In developing fish production the following aspects have been kept in mind. Operation of the artisanal fisheries is confined to a relatively narrow area along the coast, and increasing fishing operations in this area would cause a rapid decline of the fish stocks. It is therefore necessary that when vessels are motorized there should not be an overlapping of the operational areas of the sailing vessels and the motorized boats. The Government has therefore stipulated that new motorized vessels should not be smaller than 25 GT, thus enabling them to operate further from their bases. The numbers of fishing vessels from 1960 to 1972 are shown in Table 3.

Table 3. Number of powered and nonpowered fishing boats, 1960–72.

	Powered	Non-powered	Total
1960	1,456	167,975	169,431
1961	2,211	195,429	197,640
1962	2,867	206,843	209,710
1963	2,989	212,681	215,670
1964	3,200	231,659	234,859
1965	3,342	225,429	228,771
1966	3,357	250,756	254,113
1967	3,993	268,687	272,680
1968	5,707	278,206	283,913
1969	5,319	275,314	280,633
1970	6,034	289,402	295,436
1971	7,176	277,662	284,838
1972[a]	7,268	277,439	284,707

[a] Preliminary data.

To maintain a rational utilization of fisheries resources, the Government is carrying out stock assessment surveys with the objective of formulating more effective regulations on number of vessels and type of fishing gear permitted for operations in certain areas.

Development of marketing and encouragment of production will create needs for more facilities and infrastructure. For these purposes, financial resources are needed besides those supplied in the Government budget. These are obtained from foreign aid, either as grants or loans.

In addition to development of the sea fisheries there are bright prospects for development of brackish water ponds, especially for milkfish (*Chanos chanos*) and shrimps. Table 4 shows the growth in the area of fish ponds in Indonesia from 1960 to 1972. Some loan requests to international banks are being finalized to implement projects on artisanal fisheries in Java, i.e. fresh fish marketing, motorization of the sea fisheries fleet, and brackish-water pond culture.

For development of artisanal fisheries, because of the vastness of the Indonesian territory and the limited budget available, it has been found necessary to establish priorities.

TABLE 4. Area of fish ponds in hectares, 1960–72.

	Brackish water	Fresh water	Paddy field	Total
1960	145,144	30,179	91,570	266,893
1961	144,710	33,861	113,273	291,844
1962	153,063	53,904	117,014	323,981
1963	150,078	34,674	105,186	289,938
1964	109,512	38,101	109,407	257,020
1965	164,588	36,102	101,014	301,704
1966	165,409	34,257	139,081	338,747
1967	165,007	39,552	120,802	325,361
1968	167,239	34,124	105,984	307,347
1969	177,061	35,168	75,197	287,426
1970	179,911	40,023	85,340	305,274
1971	183,799	36,167	70,437	290,403
1972[a]	183,800	36,200	70,400	290,400

[a] Preliminary data.

DEVELOPMENT OF COMMERCIAL FISHERIES

The objective for commercial fisheries is to produce commodities for export and thus increase foreign exchange earnings. Some commodities in high demand on the international market, like shrimps, skipjack and tuna, are found in abundance in Indonesian waters. Development of commercial fisheries is mainly directed at these three. To stimulate capital investment in fisheries, the first step taken was to give opportunities for foreign investment in the shrimp industry, which seemed to be attractive. Establishment of joint ventures has attratced domestic capital, and within a relatively short period significant amounts have been invested.

To prevent unnecessary conflicts between artisanal and commercial fisheries it has been ruled that commercial fisheries should operate outside the limits where the artisanal fisheries work. It is also specified that commercial fisheries should operate only for the export market; otherwise they would compete unfavorably with artisanal fisheries in the domestic market.

Because of the large amount of capital needed for commercial ventures, prototype vessels are being prepared to study the feasibility of these fisheries. If these are successful the investment in fisheries will increase considerably.

IMPROVEMENT OF FISHERIES ADMINISTRATION

The objective of this program is to develop an effective and efficient administration, capable of carrying out the tasks of fisheries development. Reorganization of the Central and Regional Fisheries agencies is being carried out to produce a simplified and more coordinated system. Upgrading of staff and personnel according to their job qualifications is an integral part of this effort.

Fisheries training and education are being reviewed and rescheduled to cover only the subjects most needed for preparation of crews and other personnel for the artisanal and commercial fisheries.

Research activities are being intensified, with special emphasis on current problems encountered by the fisheries industry. Research institutes are working on an integrated program with the objective of arriving at practical and thorough solutions of problems.

To speed up fisheries development, the role of extension work is not being overlooked. Intensive efforts are being made to reorganize and update the extension services as part of the Central and Regional Fisheries agencies.

Present Situation of Fisheries Development

Enactment of the foreign capital investment law (1967) and domestic capital investment law (1969) have resulted in establishment of eight domestic companies, with a total investment of approximately $27 million (US). According to investment regulations, those companies must engage in integrated fishery projects, involving catching fleets and processing plants. Normally the projects must be in waters where intensive exploitation by local fishermen has not taken place, thus achieving a rational distribution of fishery facilities and activities and preventing unnecessary concentration in small areas.

Since 1969 exports of fishery products have significantly increased in volume and value. Shrimps are the most important export commodity, accounting for 55% of the volume and 85% of the value in 1972 (Table 5).

In response to the advancement made by large-scale fishing industries, domestic capital of moderate scale has started to move into fisheries, especially the shrimp business. More than 800 small shrimp trawlers (10–15 GT) are exploiting the shrimp grounds east of Sumatra and north of Java. Existence of cold storages in certain places in Sumatra and Java has encouraged artisanal fishermen to engage in selective fishing for marine shrimps and to collect brackish-water shrimps thus obtaining better earnings and changing their old patterns of fishing and handling the catch.

To stimulate the domestic marketing of fresh fish, steps have been taken to set up pilot marketing projects involving a cold chain system, beginning on the island of Java in 1972 and to be followed on the island of Sumatra in 1973. The purpose of this system is to preserve fish in fresh condition to the last part of the marketing chain. Socially, this will involve a change in the habits of artisanal fishermen by encouraging them to produce fish of high quality in terms of both species and freshness, and of the people by gradually orienting them to consume fresh fish, thus improving their nutritional intake. Economically, it will provide better earnings for the small fishermen. Cooperative societies will be used as the agencies engaged in the marketing activities.

Success in the marketing aspects would help establish the basic structure for further development of the artisanal fisheries as an active component of general fisheries development.

Expectations

At the end of the first 5-year development plan (1969–74) the following targets are expected to have been achieved: establishment of large-scale fishing industries, capable of exporting shrimp, skipjack, tuna, and other commercially important species in an approximate amount of $30–40 million (US) per year; establishment of marketing facilities for fresh fish distribution in the most populated areas in Java, Sumatra, and other places; raising the artisanal fisheries to a level of readiness where they can independently sustain growth; establishment of effective research systems capable of providing basic and applied data for better resource management; establishment of effective education and training systems capable of meeting the rising demands for technically and managerially skilled personnel; establishment of fisheries cooperatives as an institutional means to promote development of entrepreneurship in artisanal fisheries; improvement of the central and regional government fisheries services.

TABLE 5. Percentage of export value of fishery products, 1960–1972.

Commodity (1)	1960 (2)	1961 (3)	1962 (4)	1963 (5)	1964 (6)	1965 (7)	1966 (8)	1967 (9)	1968 (10)	1969 (11)	1970*) (12)	1971*) (13)	1972**) (14)
Shrimp:													
—Fresh	3	5	5	12	—	—	...	1	25	36	61	77	85
—Processed	—	—	—	—	1	—	1	5	4	4	1	...	...
Fresh fish	9	11	15	33	2	—	—	54	18	13	2	5	2
Frog leg	—	—	—	—	—	—	—	—	—	...	4	2	2
Ornamental fish	—	—	—	—	—	—	...	...	1	1	1	...	...
Others	88	84	80	55	97	100	99	40	52	46	31	16	11
Total	100	100	100	100	100	100	100	100	100	100	100	100	100

Source: Central Bureau of Statistics.
*) Revised data.
**) Preliminary data.
... Less than 0.5%.

TABLE 5a. Percentage of export volume of fishery products, 1960–1972.

Commodity (1)	1960 (2)	1961 (3)	1962 (4)	1963 (5)	1964 (6)	1965 (7)	1966 (8)	1967 (9)	1968 (10)	1969 (11)	1970*) (12)	1971*) (13)	1972**) (14)
Shrimp:													
—Fresh	1	1	1	2	—	—	...	1	13	24	31	49	55
—Processed	—	—	—	—	...	—	...	2	2	2	2	1	2
Fresh fish	3	3	5	4	1	—	—	15	17	11	6	13	9
Frog leg	—	—	—	—	—	—	—	—	—	...	3	2	2
Ornamental fish	—	—	—	—	—	—	...	...	...	...	...	...	...
Others	96	96	94	94	99	100	100	82	68	63	58	35	32
Total	100	100	100	100	100	100	100	100	100	100	100	100	100

Source: Central Bureau of Statistics.
*) Revised data.
**) Preliminary data.
... Less than 0.5%.

Prospects for the Development of Brackish-Water Fish and Shrimp Culture in India[1]

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Brackish-water fish and shrimp culture exists in several localities in India, but the total area used was only 10,000 ha in 1968 and might reach 15,200 ha by 1973. Some of this is in paddy fields used alternately for crops.

Natural sources of seed (fish fry and shrimp larvae) are used exclusively. Usually these simply enter the ponds from the estuary during high tide periods. Production averages about 200 kg/ha per year.

The potential for increasing brackish-water culture is great. Capital requirements are not excessive, and a return of 15% per annum is suggested under average conditions. Development can be encouraged by surveys of suitable areas, by experimental work on capturing and transporting seed, by artificial spawning for the production of fry of the most desirable species, and by pilot projects to test methods of supplementary feeding and other practices.

L'élevage des poissons et des crevettes en eau saumâtre est pratiqué dans plusieurs localités indiennes, mais la superficie totale utilisée n'était que de 10,000 ha en 1968; celle-ci pourrait atteindre 15,200 ha en 1973. Une partie de cet élevage se fait en rizières.

On utilise exclusivement des sources naturelles de peuplement (alevins de poissons et larves de crevettes). Dans la plupart des cas, le frai pénètre simplement de l'estuaire dans les étangs à marée haute. La production est en moyenne de 200 kg/ha par an.

L'élevage en eau saumâtre présente des possibilités énormes d'expansion. Les besoins en capitaux ne sont pas excessifs et un bénéfice de l'ordre de 15% par an pourrait s'obtenir dans des conditions moyennes. Pour encourager le développement, diverses activités sont à envisager: prospection de zones appropriées, recherche expérimentale sur la capture et le transport du matériel de peuplement, reproduction artificielle pour l'obtention d'alevins d'espèces les plus recherchées et réalisation de projets pilotes pour expérimenter des méthodes de nourrissage complémentaire et d'autres techniques.

El cultivo de peces y camarones en aguas salobres se practica en varias localidades de la India. La superficie total destinada a este fin era en 1968 de sólo 10,000 ha y tal vez llegue a 15,200 ha en 1973. Parte de esta superficie son arrozales utilizados rotatoriamente para la producción agrícola.

Se utiliza exclusivamente semilla de peces procedente de fuentes naturales (alevines y larvas de camarones). De ordinario se deja simplemente que entren en los estanques des de el estuario durante los períodos de marea alta. La producción media es de unos 200 kg/ha al año.

Las posibilidades de aumentar la piscicultura en aguas salobres son enormes. Las necesidades de capital no son excesivas y en condiciones medias podrían obtenerse beneficios del 15% al año. Para fomentar el desarrollo de la piscicultura es preciso examinar las zonas adecuadas, realizar trabajos experimentales sobre captura y transporte de semillas, promover el desove artificial para la producción de alevines las especies más deseables, y organizar proyectos piloto para ensayar métodos de alimentación complementaria y otras prácticas piscícolas.

SCIENTIFIC brackish-water fish and prawn culture had previously been generally limited to a few countries of the Indo-Pacific and Mediterranean regions, but in recent years all developing countries have been seriously considering the possibility of reclaiming extensive saltwater areas for aquaculture. Accurate estimates of the extent of estuarine waters in India which are suitable for aquaculture are not yet available, but information so far collected tends to show that about 2 million ha of such water areas should be available in different parts of the country.

The brackish-waters of immediate concern for fish cultural purposes are estuarine basins, backwaters, tidal creeks, brackish-water lakes, and coastal lagoons. Most of the brackish-water systems in our country are characterized by a strong monsoon rainfall regime that allows freshwater discharge during a limited period of the year,

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although the intensity of this influence tends to decrease from north to south. Similarly, there is a decrease from north to south in tidal oscillations, which are well developed in the northernmost estuary (the Hooghly) but are comparatively small in the southernmost ones like the Cauvery. Such phenomena result in drastic variations in the estuarine environment from region to region.

Present Status of Brackish-Water Fish and Prawn Culture

The culture of brackish-water fish and prawns in India has, till recently, been based on traditional and empirical methods. Such practices, in essence, relate to raising temporary bunds or barriers enclosing the tidal water, thus retaining the available fish and prawns for a short period until they grow to marketable size. This system is not fish culture in the real sense of the term but is generally known as "trapping-cum-holding." In different parts of the country, like the Sunderbans in West Bengal and the backwaters of Kerala, variations of this method are found, depending on physiography and characteristics of the ecosystem.

"BHASABADA" SYSTEM OF WEST BENGAL

This system of brackish-water fish culture is prevalent in the Sunderbans region of West Bengal. It is based on trapping-cum-holding practices in shallow reservoirs formed by construction of low earthen embankments, which tidal water enters through suitable sluices. Fry and juvenile mullets, prawns, bhetki, etc., get into the reservoirs, popularly called "bheris," with the tidal water during the high tide phases. They are held from about May/June to February, after which they are fished and the produce marketed.

The Sunderbans "char" lands, which will not be suitable for raising agricultural crops for many years to come, can be profitably used for brackish-water fish and prawn culture.

The fish production from "bheris" is reported to vary from 100 to 1000 Kg/ha, the average being about 200 kg/ha per year.

PRAWN FILTRATION TECHNIQUE IN KERALA

In Kerala, prawns constitute the mainstay of the brackish-water fish culture industry. The principle involved is the same as in the case of "Bhasabada" fisheries of the Sunderbans, and the industry thrives over an area of more than 5000 ha of paddy fields in the Vembanad Lake region. The production of prawns and other fishes from these fields is in addition to the seasonal paddy crop. By the close of the paddy season, the backwaters become more saline and the fields are inundated. Large, rectangular sluice boxes with open ends are then fitted between the paddy fields and the tidal creeks. Swarms of postlarval prawns enter the field with the water current and are retained there for the next few months for growth. At the end of this time the crop is harvested by draining the water out through the sluices fitted with conical bag nets. The production of prawns in these fields is reported to vary between 300 to 1000 kg/ha per year.

SCIENTIFIC BRACKISH-WATER CULTURE

Scientific culture of brackish-water fish and prawns has recently been taken up in a few experimental farms in the country. The earlier attempts were made in Kerala by constructing some farms such as Narakkal, Malipuram, Kadappuram, and Ayiramthengu, along the coastal belt of the state. The first two of these farms have shown interesting results. For operation of these farms, the fingerlings of important species, especially mullets, are collected from neighboring canals for stocking.

The Central Inland Fisheries Research Institute has constructed a brackish-water farm at Kakdwip (West Bengal) where experiments on the culture of mullets, prawns, and bhetki (*Lates calcarifer*) are in progress. Among the significant results so far achieved at the farm are those relating to monoculture of the mullet, *Mugil parsia*, and of the prawn, *Penaeus monodon*. For *M. parsia*, production rates up to 2400 kg/ha in 210 days have been obtained, with rice bran and mustard oil cake as supplementary feed. For the prawn, production rates up to 620 kg/ha have been obtained in 270 days without any artificial feed. Trials of different types of feeds are in progress. *P. monodon* has attained an average length of about 210 mm in 270 days, which appears to be quite attractive for export, there being considerable demand for jumbo prawns.

FISH SEED RESOURCES

For the purpose of developing brackish-water fish culture in India, the two essential prerequisites are a survey of potential areas, and the production and/or collection of seed of culturable species of brackish-water finfish and shellfish. Until such time as production of brackish-water seed is achieved by induced breeding, and hatchery techniques are developed, collection of seed from natural sources is a *sine qua non* and has to be depended upon exclusively.

Fortunately, most of the brackish-water systems in the country have been found to be dependable sources of fish and prawn seed. Detailed data on seed resources have been collected from Hooghly-Matlah estuarine system in West Bengal, Chilka Lake in Orissa, Pulicat Lake in Tamil Nadu, and the backwaters of Kerala. In addition, data on the annual collection of milkfish fry and fingerlings from different regions of Tamil Nadu are also available.

The quantities of brackish-water fish fry collected in the different states indicate that a total of not more than about 5 million fry are being collected in any year in India for culture purposes. It is obvious that this is only a meagre fraction of what is freely available.

Economics of Brackish-Water Culture of Fish and Prawns

One of the important considerations in the development of brackish-water fish culture in India is the large extent of estuarine areas available in different regions, most of which cannot be profitably used for any other productive purpose. Thus the scope for developing the industry is immense, provided correct scientific methods and techniques are followed. A reasonable projection of the economic viability of brackish-water fish and prawn culture, based on the technical knowhow so far developed, is shown in Table 1, and it appears attractive. It is felt that holdings between 10 and 20 ha in area will prove to be the best suited for culture purposes.

TABLE 1. Analysis of costs and income for brackish-water culture.

		Rs.	Approximate equivalent in US $
	Capital investment (per ha)		
1	Land	6000	833
2	Pond construction	10000	1389
3	Sluices	1000	139
4	Farm buildings	1100	153
5	Farming equipment	1400	194
		19500	2708
	Recurring production costs (per ha per year)		
1	Fish seed	250	35
2	Fertilizers	635	88
3	Feeds	120	17
4	Wages	1440	200
5	Pond preparation and maintenance	250	35
6	Transport	75	10
7	Miscellaneous	200	28
	Total	2970	413

Income

Fish production: 1500 kg at Rs. 4/kg = Rs. 6000 ($833)
Net return (Project): Rs. 6000 – Rs. 2970 = Rs. 3030 ($421)
Rate of return on capital: 15.5%

These economic indicators reflect the economic viability of brackish-water fish culture operations at expected levels of production and of expenditure pattern.

Recommendations

Taking into consideration the vast estuarine tracts available in the country for development of brackish-water culture, the considerable resources of fish seed in at least the major estuarine systems, the encouraging experimental results so far obtained on the culture of mullets and prawns, and the public demand for brackish-water species (especially prawns) both for local consumption and for export, the following recommendations aimed at developing the brackish-water culture industry in the country are made.

Since the present utilization of the brackish-water fishery culture resources of India (estimated at about 2 million ha) are negligible, urgent steps are required to develop such fisheries.

Since the paucity of detailed knowledge on the sources and availability of the seed of brackish-water fish is a serious problem hampering brackish-water fish culture, seed prospecting investigations using a standard methodology should be conducted in the estuarine systems of the Rivers Ganga, Godavari, Kistna, Cauvery, Tapti, and Narmada, and in potential regions like Kutch, Goa, etc. Seed prospecting should also be urgently done in or near natural brackish-water lakes such as Chilka, Pulicat and the backwaters of Kerala, where great scope for developing brackish-water farms exists. Standardized methodology for brackish-water fish seed prospecting should be prepared expeditiously.

To help solve the problem of availability of brackish-water seed, hypophysation of prime culturable brackish-water fishes, viz. *Lates calcarifer*, *Mugil cephalus*, *M. tade*, *M. parsia*, *M. macrolepis*, *Eleutheronema tetradactylum*, *Polydactylus indicus*, and *Chanos chanos*, should be attempted on priority basis. Laboratories with running brackish-water facilities should be provided at suitable locations in the country.

Suitable methods for the transport of the seed of culturable brackish-water fishes and prawns may be developed by experimentation. This will lead to the establishment of a brackish-water fish seed industry.

As development of brackish-water pond management practices cannot brook any further delay, work on the formulation of such practices should be accentuated in well planned brackish-water experimental farms and carefully planned pilot projects.

A collaborative research program on development of artificial feed for prime culturable brackish-water fishes should be formulated.

Prawn export in the frozen, canned, and dried state has come to be a very important source of foreign exchange, of the order of about Rs. 347 million in 1971. To safeguard the expanding foreign trade as well as to cater to the demand within the country, pilot projects on exclusive farming for prawns may be set up in Sunderbans, Chilka, Pulicat, Kerala backwaters, Goa and Kutch regions.

The area under brackish-water fish farming in the country is likely to increase from 10,000 ha in 1968 to 15,200 ha by 1973. It is necessary to reclaim swamps and marshes into brackish-water farms at a more rapid rate than hitherto. Since the reason for the slow progress is lack of knowledge concerning areas suitable for reclamation, it is necessary to conduct rapid surveys following a standard methodology.

Farming of edible oysters and mussels in brackish-waters has not yet been taken up in India along scientific lines, and it is necessary to set up pilot studies in this direction at suitable locations.

Report on Technical Session IV — Section 3

1. A significant part of the gap between the projected world potential production of 100 million tons and the present level of 69–70 million will be filled from the Indian Ocean, where the absolute level relative to the potential is much lower than elsewhere. Catches by countries outside the area are still only about 8% of the total but are increasing rapidly. It appears essential that early steps be taken to achieve effective management.

2. The experience of the countries bordering the Indian Ocean should prove to be of great value to other countries at various stages of development.

Development

3. Development of the fisheries is urgent, but it must be timely and correspond to local realities.

4. The two basic elements for development were suggested to be know-how and the intention of governments. One was not effective without the other. Know-how must involve not only knowledge of resources but technical, social, and economic factors and their interrelationships as well. Know-how also involved the choosing of directions, and the pace of development. Assistance from outside must be provided in harmony with the intentions of the recipient country and not on the basis of what the donor country thinks is best.

5. Adequate attention should be given to small-scale fisherman. He often finds it difficult to adjust to other activities because he has usually been engaged in a fishery from a young age. Moreover, in developing countries there is often the problem of low employment, so that a displaced artisanal fisherman may be made jobless.

6. Experience of such programs as the Indo–Norwegian Project one suggests the importance of development arrangements being tailored to the needs of the country, and the requirement that the approach be simultaneous in related fields and be coordinated on the spot rather than from head offices of national or international agencies. The integrated approach in all fields — exploration, research, training, boat building, marketing, and extension — has been rewarding.

7. Development depends fundamentally on a series of trials and errors as well as achievements. Learning from mistakes of others should apply not only to developing countries but also to experts from any country.

8. It was stressed that people coming from outside the area must build up a meaningful relationship with the local people. On the other hand, international agencies and experts should not become too dependent on local sources of information which they are not in a position to check.

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9. On more specific points it was suggested that FAO assistance in improving the catching efficiency of vessels would be of great value.

10. In addition to cooperation among developed and developing countries, partnership among developing countries should be strengthened to make better use of fishery resources and to gain valuable experience from one another. Many problems can be solved best by a regional approach.

Joint Ventures

11. Various criteria for joint ventures were referred to, including such primary criteria as stock assessment and the hospitality of the riparian state, together with secondary criteria such as integrated organization of infrastructure and of processing and marketing arrangements.

12. Joint ventures usually involve private capital from outside the developing country. They can be of great value in providing both technical capacity and capital that would not otherwise be available. However, some countries have hesitated to adopt the system because of fear that the foreign partner may not pay adequate attention to the opinion and realities of the country concerned. The foreign partner may, for instance, be more interested in short-term profits than in long-term gains because successful private investment must involve profits. Sometimes, too, there is little enthusiasm for training local fishermen and local manufacture of equipment. Nevertheless, there are many cases of joint ventures that have proven beneficial to both parties.

13. Japan has had extensive experience with the joint venture system. It was pointed out that to be successful the joint venture must keep fully in mind the national interest of the recipient country, which on its side should take necessary steps to conserve resources, prevent conflicts on the fishing grounds, and enable the outside partner to operate without excessive competition. The necessary infrastructure should also be provided.

14. Recipient governments should recognize the risks inherent in fishery ventures and the need for exploratory and experimental fishing. It was mentioned that arrangements should be made for the ultimate transfer of the operation to the recipient country.

Aquaculture

15. The potential for increasing brackish water and inland fish culture is large. Vast areas of mangrove swamps exist which are generally thought to be potential culture areas. However these are important nursery areas for shrimp, fish, and molluscs. A study is being carried out by the Indian Ocean Program to quantify this. This will be followed by economic studies of alternative land uses, so that administrators will have specific information

on which to base decisions on the uses to which mangrove swamps should be put.

16. Other studies are going on in Malaysia (where a Brackish Water Station is to be established) and in Mozambique, while extensive field programs are under way in India.

17. Aquaculture may prove to be very useful for inland fishermen, who are often widely scattered throughout the country. Both inland and along the coast, aquaculture could provide a useful alternative for artisanal fishermen engaged in the marine fishery. There appears to be a definite role for this activity in the overall development of the area.

Training

18. It should not be overlooked that while scientists provide data and governments issue regulations, it is ultimately the fishermen who have to live by the regulations. One part of their education, therefore, should cover the reasons why they should not engage in activities detrimental to themselves collectively. A great deal could be done with imaginative films; at the moment the useful ones are out of print and others are limited in subject matter. In this connection, as well as for training the fishermen in general, demonstration or "show-how" is probably the best way.

19. Training is important not only for people who are engaged directly in fisheries operations but also for those involved in planning and research.

20. Much could be learned from experiences both in the countries of the area and in other parts of the world. Reference was made to the extensive fishery training program in Mexico from which many lessons of wide application could probably be learned. There was also an explanation of the training work being undertaken by the Southeast Asian Fishery Development Centre.

21. There is scope for regional cooperation to avoid wastage by using and upgrading existing facilities as regional centers. New centers are required for other skills.

22. It was felt that FAO could add a great deal to ensure that the results of world-wide experience were made readily available.

23. Reference was made to experience in Thailand which suggested that sophisticated training was not necessary for upgrading the coastal fishery. A review should be made of present training programs in the region. It was pointed out that this situation was quite different from that in Korea where the issue was training for the operation of a deep sea fleet.

Management

24. There is not much management of the resource in the area now, but the outlook is generally good because exploitation is not yet up to potential capacity. There is still time to take advantage of the extensive history of management experience throughout the world. The need was stressed for continual watching of the resources, based on the experience in Thailand.

25. Impediments to management include lack of information necessary for effective decision making, or of methods for operating from insufficient data; allocation of common-use resources to ensure most effective exploitation; difficulties of enforcement; and fear by countries not now engaged in a fishery that management schemes introduced now may act to prevent their subsequent entry.

26. The opinion was expressed that inadequate information is available on the fisheries of the coastal waters of much of the area because scientists have tended to center their research on the more productive parts of the ocean.

27. On the statistical side, the view was expressed that FAO could initiate a program to assist the Indian Ocean countries in the development of effective biological statistics essential for management. FAO could indicate the data needed, how they should be collected and how analyzed.

28. Government administrators in the area have to assess present and prospective requirements in the light of the needs of the country. In the absence of necessary data, they may have to use the experience in developed countries which may not be applicable and hence undertake new programs without sufficient preparation.

29. During the discussions reference was made to such organizations as the Indo Pacific Fisheries Council, established in 1949, and the Indian Ocean Fishery Commission established in 1967, both under FAO, and to the Indian Ocean Program under the IOFC designed to promote fishing development.

30. A successful bilateral arrangement exists between Thailand and Malaysia and it is expected that a similar arrangement will soon be concluded between Malaysia and Indonesia.

FAO Technical Conference on Fishery Management and Development

TECHNICAL SESSION IV — SECTION 4

Regional and Other Case Studies — North Pacific

CHAIRMAN: D. L. ALVERSON, UNITED STATES

Management of Fisheries in the North Pacific[1,2]

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Kasahara, H. 1973. Management of Fisheries in the North Pacific. J. Fish. Res. Board Can. 30: 2348–2360.

Resources in the northwestern Pacific and the Bering Sea are fished intensively and the potential increase in the yield of traditional species does not appear great. In contrast, waters from the Gulf of Alaska to off Baja California are lightly fished, except for a few species, and contain large potential resources, particularly of pelagic species. Countries bordering this ocean differ greatly from each other in the concepts and methods of domestic fishery management as well as in the degree of control by government. The overwhelmingly large part of the combined total catch comes from fisheries which are at present not subject to international regulation. The international regulatory regime consists of various conventions and short-term agreements designed to solve immediate issues. No comprehensive arrangements exist and principles of management differ from case to case. Among the major management problems are: fluctuations in the yields of coastal pelagic species; rapid expansion of pollack fishing in the northern areas; lack of inclusive agreement for fisheries in the East China and Yellow Seas; management of salmon fisheries; and development of new resources particularly in the eastern Pacific.

Les ressources du Pacifique du nord-ouest et de la mer de Béring font l'objet d'une pêche intensive et il ne semble guère possible d'augmenter le rendement des espèces classiques. Par contre, les eaux allant du golfe de l'Alaska jusqu'au large de Baja California sont faiblement exploitées sauf pour ce qui est de certaines espèces, et offrent un vaste potentiel, notamment en espèces pélagiques. Les pays limitrophes de cet océan diffèrent beaucoup les uns des autres par les concepts et les méthodes d'aménagement de leurs pêches nationales, ainsi que par le degré de contrôle gouvernemental. Une écrasante majorité des prises provient de pêcheries qui ne sont pas actuellement soumises à la réglementation internationale, dont le régime consiste en conventions et accords à court terme divers, conclus pour résoudre les problèmes immédiats. Il n'existe pas de règlements généraux et les principes d'exploitation varient selon les cas. Voici quels sont, entre autres, les principaux problèmes que pose l'aménagement des stocks: fluctuations du rendement des espèces pélagiques côtières; expansion rapide de la pêche du lieu dans les régions septentrionales; absence d'un accord général sur les pêches dans la mer de Chine orientale et la mer Jaune; aménagement des pêcheries de saumon; développement de ressources nouvelles, notamment dans le Pacifique oriental.

Los recursos del Pacífico noroccidental y del Mar de Bering son explotados intensamente y, a su vez, el aumento potencial del rendimiento de las especies tradicionales no parece ser grande. Por el contrario, las aguas desde el Golfo de Alaska hasta la Baja California están ligeramente explotadas, si se exceptúan algunas especies, y contienen grandes recursos potenciales, particularmente de especies pelágicas. Los países que bordean este océano varían grandemente entre sí en los conceptos y métodos de ordenación de las pesquerías nacionales y también en el grado de control por parte del gobierno. La parte más considerable de la captura total conjunta proviene de pesquerías que en la actualidad no están sometidas a reglamentaciones internacionales. El régimen regulatorio internacional consiste en varios convenios y acuerdos a corto plazo destinados a resolver problemas inmediatos. No existen acuerdos generales y los principios de la ordenación varían de uno a otro caso. Entre los principales problemas de ordenación figuran los siguientes: las fluctuaciones en los rendimientos de las especies costeras pelágicas; la rápida expansión de la pesquería de abadejo en los mares del norte; la falta de un acuerdo que incluya las pesquerías del Mar de la China Oriental y las del Mar Amarillo; la ordenación de las pesquerías de salmón; y el desarrollo de nuevos recursos particularmente en el Pacífico oriental.

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

[2] This paper is partially drawn from a study by the author and Professor William T. Burke (University of Washington) for the Program of International Studies of Fishery Arrangements, undertaken by the Resources for the Future, Inc.

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THIS paper reviews the present and probable future problems of fishery management in the North Pacific Ocean. For this purpose, the region is defined as Pacific waters north of the tropics, including adjacent seas (the Bering Sea, the Sea of Okhotsk, the Sea of Japan, and the East China and Yellow seas). This excludes from present consideration fisheries for tunas in tropical waters; problems of tuna fisheries are covered on a global basis by Joseph (1973). Exclusion of the tropical part of the North Pacific eliminates discussions of management problems in Southeast Asia, which differ in many ways from those in the areas further north. Management of whales is excluded as this is covered by Chapman (1973).

There is no recent monograph of North Pacific fisheries. Reviews by Kasahara (1961 and 1964) do not include developments in the last 10 years. A large number of individual papers published by VNIRO of USSR (1963, 1964a, 1964b, 1965, and 1970) discuss the results of intensive investigations carried out in the Bering Sea and the north-eastern part of the Pacific proper; many other papers covering different aspects of North Pacific fishery resources have been published in recent years. It is not possible to review these in the present paper. The potentials of resources in the region are assessed in "The Fish Resources of the Ocean" edited by Gulland (1971).

State of Exploitation of Resources

Some features of the general oceanography of the region reflect the distribution of major fishery resources, both existing and potential. Nearly all fishing for demersal species is conducted on the continental shelf and the upper half of the slope. Development of fishing technology will make it economically feasible to exploit demersal species to a depth of 1000 m or greater, at least in some parts of the region, but it will still be within the limits of the continental slope. Furthermore, many of the important coastal pelagic fish resources occur largely in waters of the shelf and slope.

Shelf areas of large to medium expanse are found from the Gulf of Alaska to the East China Sea. Particularly large areas occur in the Bering Sea, the Okhotsk Sea, and the East China Sea (including the Yellow Sea). The northern part of the Bering Sea shelf and the large shelf area in the northern Sea of Okhotsk are of limited importance to fisheries because of low bottom temperatures prevailing even in the summer, near or below 0 C. Bottom animals in the shelf areas of the northeastern Pacific, the Bering Sea, the Sea of Okhotsk, the Sea of Japan, and in the waters off the Kuril chain and northern Japan, are principally subarctic (or arctic in the northern parts

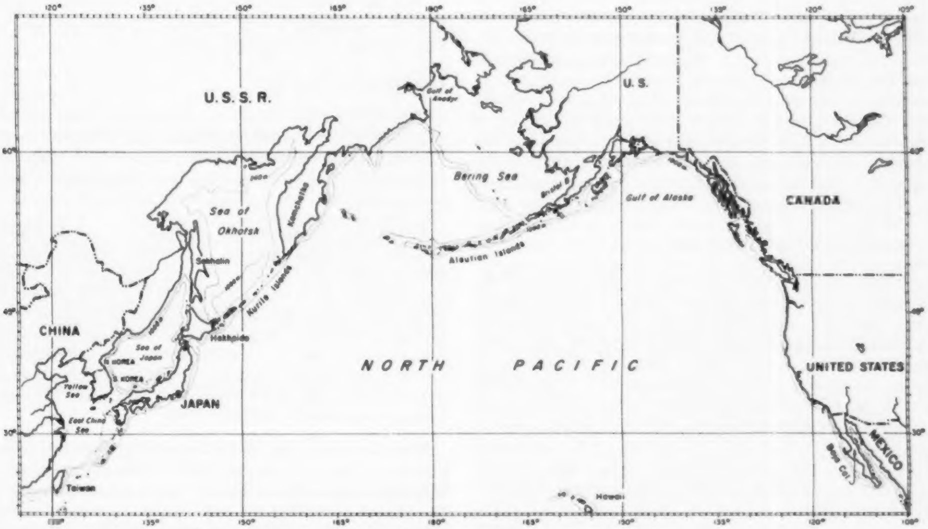
120°
135°
150°
165°
180°
165°
150°
135°
120°
105°
60°
45°
30°
U. S. S. R.
Gulf of Anadyr
U. S.
Bering Sea
Bristol B.
Gulf of Alaska
CANADA
Sea of Okhotsk
Kamchatka
1000
Sakhalin
Kurile Islands
Aleutian Islands
CHINA
Hokkaido
Sea of Japan
N. KOREA
S. KOREA
Yellow Sea
JAPAN
East China Sea
Taiwan
N O R T H
P A C I F I C
UNITED STATES
MEXICO
Baja Cal.
Hawaii
120°
135°
150°
165°
180°
165°
150°
135°
120°
105°

FIG. 1. Map of the North Pacific, showing the 200-m and 1000-m depth contours.

of the Bering Sea and the Sea of Okhotsk). Those in the East China Sea are largely temperate demersal species.

Another important oceanographic feature is the difference between the western and eastern parts in the distribution of surface temperatures. Because of the general circulation of water in the region and the strong influence of continental climate on the Asian side, the western half and its adjacent seas are characterized by much greater seasonal temperature changes in the upper zone than those in the eastern half of the Pacific Ocean. This causes sharp boundaries resulting in marked seasonal movements and concentrations of pelagic species.

Primary production is often used as a rough indication of potential yields of animals at higher trophic levels, even though such data may be misleading, especially in waters of high latitudes where phytoplankton grow at a rapid rate for a relatively short period of time. Most zooplankton data are expressed in terms of biomass rather than production, and may not relate directly to yields at higher levels. There is, however, a general similarity between both these measures and the pattern of distribution of exploitable fish resources. Koblentz-Mishke et al. (1970) compiled available primary production data for the world oceans, and a more generalized map is found in the Atlas of the Living Resources of the Sea (FAO 1972b). Both show that waters of high primary production are along the rim of the Pacific Ocean and in areas of divergence associated with the equatorial current system. Similar features are obvious in a generalized map for zooplankton biomass contained in the same FAO atlas. Except for those for tunas, most of the good fishing grounds are along the rim of the ocean. Waters of the equatorial current system are known to contain abundant resources of unutilized species and also coincide with some of the major tuna fishing grounds. A more important aspect of oceanographic data summarized in those figures is the existence of a vast area in the central part of the North Pacific where indices of productivity are low, and where large untapped resources are unlikely to be found.

NORTHWESTERN PACIFIC AND BERING SEA

The resources in waters around the Japanese Islands, the East China Sea (including the Yellow Sea), the Korean and USSR coasts of the Sea of Japan, and various parts of the Sea of Okhotsk, have been fished for many years, with the intensity increasing sharply after World War II. In the last 15 years heavy fishing has expanded to the Bering Sea and the Kamchatka–north Kuril area, as well as some parts of the northeastern Pacific. The northwestern Pacific (including its adjacent seas) and the Bering Sea now represent one of the most intensively fished areas of the world oceans. The resources of familiar species are heavily exploited by Japan, the USSR, South and North Korea, and China. In the eastern Bering Sea, the United States catches salmon, crabs, and halibut. Most stocks of commercially important demersal species occurring to a depth of approximately 500 m, both fishes and invertebrates, are either fully exploited or overfished, so that in general their catches will not increase as fishing is further intensified.

In recent years the continuous increase exhibited by the total catch of demersal forms has been sustained by one species, the pollack (*Theragra chalcogramma*). The combined catch of pollack by Japan, the USSR, and North and South Korea accounts for nearly 30% of the total catch of all marine species from the northwestern Pacific and Bering Sea. Problems arising from rapid development of pollack fisheries will be discussed below.

Another important aspect of exploitation of living resources in the region is violent fluctuations in the catches of major coastal pelagic species, also discussed below. The question of how to manage these resources has been perplexing to both scientists and administrators, and solutions, if any, are yet to be found.

Such high value species as Salmon (*Oncorhynchus*) and crabs (particularly *Paralithodes* and *Chionoecetes*) are fished by Japan, the USSR, and the United States under international agreements, but no long-term increase in total catch is expected.

In summary, the total catch of traditional species exploitable by traditional methods is apparently close to a maximum level in this area, with some uncertainties about the future of the pollack catch. Not many unutilized stocks are known to exist except such forms as sandeels (*Ammodytes*) or osmerids in northern waters. The pomfret (*Brama raii*) is found in wide areas across the Pacific, but its total abundance may not be large. An increase of one or two million tons a year might still be feasible, but this would be a small amount relative to the present total catch estimated at over 13 million metric tons.

The fisheries of pelagic species will continue to be subject to short-term as well as long-term fluctuations, and their causes are still largely undetermined.

NORTHEASTERN PACIFIC

Waters from the Aleutians to off Baja California are in general only moderately exploited. The estimated present total catch (including the entire United States tuna catch in the eastern tropical Pacific) is a little over 1 million tons a year.

Fishing by Canada and the United States in this area is selective, for such species as salmon, tuna, crabs and shrimps, halibut (*Hippoglossus stenolepis*), and some other groundfishes. The only distant-water fishery is the tuna purse-seine fishery operating in the eastern tropical Pacific off the coast from southern California to northern Chile. Substantial amounts of ocean perch (*Sebastes alutus*) are taken by the USSR and Japan in the Gulf of Alaska, and hake (*Merluccius productus*) by the USSR in waters further southward (Alverson 1968.)

Potential resources of traditional species now underutilized or completely untouched include at least anchovy (*Engraulis mordax*), some other clupeoids, jack mackerel (*Trachurus symmetricus*) and other carangids, squids, capelin (*Mallotus villosus*), saury (*Cololabis saira*), bonito (*Sarda chiliensis*), sandeels, some pandalid shrimps, and possibly herring in some areas. Groundfishes may also support a moderate increase. It is not unrealistic to expect an increase in total yield amounting to several million tons a year, if these and other resources were fully exploited. The largest amount would come from the area of the California current system including waters around Baja California.

CATCHES BY COUNTRIES

Approximate amounts of marine species (excluding whales but including marine plants) now taken by the countries bordering the northern North Pacific are as follows. The figures are not accurate but roughly indicate the present situation. Japan takes the largest quantity, roughly 8.5 million metric tons. The USSR catch from the Pacific alone is estimated at a little over 2 million tons. Excluding long-line tuna catches and trawl catches in areas other than the North Pacific, South Koreans land about 830,000 tons. No reliable estimate is available for the marine catch of China from the East China Sea (including the Yellow Sea); it might be around 1.5 million tons, plus or minus 0.3 million. About 0.4 million tons are landed in the Island of Taiwan from nearby waters. From the catch in waters off North Korea (excluding sardines which have disappeared completely) during the prewar years, the present catch of North Korea might be estimated at 0.7 million, plus or minus 0.2.

The combined Soviet and Japanese catch (not including Japanese tuna catches) in the eastern half of the Bering Sea and the northern North Pacific, more or less east of 180°, is estimated at about 2.2 million tons, the bulk of which comes from the Bering Sea.

The present Canadian catch from Pacific waters is small, about 0.1 million tons. This is due largely to a sharp decline in the British Columbia herring catch. The United States take is less than 0.7 million tons, including the tuna catch in the eastern tropical Pacific. If the latter is excluded, the figure will be a little over 0.5. This small catch is taken from an extremely long coastline from northern Alaska to southern California. The Mexican catch on the Pacific side is over 0.2 million, penaeid shrimps and sardines being among the important forms.

It is difficult to compile figures for the Pacific Ocean showing the rates of growth of the catches of the countries concerned, because important data are missing for earlier years. The trend in the 15-year period, 1955–70, based on the total catch (from all areas and including freshwater fish) of each country shown in FAO'S statistics (FAO 1972a) is as follows: Japan from 4.9 million metric tons in 1955 to 9.3 million in 1970; the USSR from 2.5 million to 7.3 million; Taiwan from 0.2 million to 0.6 million; the United States from 2.8 million to 2.7 million; Canada from 1.0 million to 1.4 million; Mexico from 0.1 million to 0.4 million.

Management Methods Used by Different Countries

As the overwhelming part (over 90%) of the total catch in the North Pacific comes from fisheries not yet subject to international regulation, it is important to understand the principles and methods of fishery management adopted by different countries of the region. But since information on the domestic regulatory systems is not available for some of them, this section is incomplete.

JAPAN

The economic structure of the Japanese fishing industry is one of extreme complexity. As of 1970 there still existed some 340,000 vessels smaller than 3 gross tons engaged in fishing in inshore waters (Ministry of Agriculture and Forestry 1972). In the same year Japan operated a large number of motherships, a fleet of giant trawlers, hundreds of large tuna longliners scattered all over the world oceans, and the world's largest whaling fleet. Between these two extremes are vast numbers of vessels of all kinds and sizes which collectively contribute the largest portion of the total production. A wide variety of fishing operations can be found even within one technical category such as trawling, ranging from many thousands of inshore draggers to the largest trawlers in the world. To a substantial degree this complex industry has developed from a unique and complicated domestic management system. Domestic institutions for fisheries have had such great effects on development of all Japanese fisheries, including those in distant waters, that some understanding of the institutional framework in which the fisheries operate is a necessary prelude to a discussion of their problems (Kasahara 1972).

While regulations under this system differ from fishery to fishery, the common and most important feature is direct control on number and types of vessels allowed to be used for a particular fishery. The application of limited entry regulations is based on a variety of considerations, and justifications used by the government for limiting entry have varied. Among apparent objectives are: protection of inshore fisheries against offshore fishing; reduction of competition and prevention of disputes among different groups of offshore fishermen; stabilization of fishing conditions; maintenance of profitability; conservation of resources; and prevention of international disputes. The degree of success in achieving these objectives has also differed.

The system has served as such a powerful and convenient means to control each fishery and to introduce

The regulatory system consists of two parts: so-called "fishing right fisheries" and "license fisheries." The former are further broken down into three categories: "demarcated fishing right," "fixed net fishing right," and "common fishing right." The first of these categories is applied mainly to aquaculture, where certain areas must be used exclusively by individual fishermen or groups of fishermen, as land is for farmers. The second category has been used for regulating large traps, which require the exclusive use of certain sites for fixing fishing gear and maintenance of some distances between them. Trap fishing rights are given either to individual operators or to cooperatives. Fishing rights under the last category are normally given to cooperatives for the purpose of managing minor fishing operations, including small traps, in inshore waters.

Most of the major fisheries fall into the general category of "license fisheries." This part of the system was introduced with the development of modern fisheries, and changes have been toward the centralization of licensing authority (from prefectural governments to central government). Virtually all offshore and distant-water fisheries are now rigidly controlled by the licensing system. This system regulates the activities of each fishery through restrictions on the total number of licenses to be issued, size of vessels to be used, area of fishing, period of fishing, method of fishing, and often the species to be taken. The operation of this system is described in detail by Asada (1973).

changes considered desirable by the fishery administration that some of the other important aspects of management are almost nonexistent on the domestic scene. Except when they are required under international agreements, the application of such measures as total catch limits, minimum mesh sizes, or minimum sizes of fish landed, has been the exception rather than the usual feature of management.

The system has resulted in the allocation of resources or fishing grounds among different fisheries or different groups of fishermen, sometimes in a complex manner. For example, regulatory measures controlling the trawl fisheries of Japan have established a pattern of allocating ground fish resources among different types of trawling: stocks in coastal and nearby waters largely to the Danish seine fishery (in the richest grounds off northern Honshu and Hokkaido) and partly to the pair-trawl fishery (in the western part of Japan); stocks in the China Sea mainly to the pair-trawl fishery and partly to the otter-trawl fishery; stocks off Kamchatka and the northern Kurils to the expanding land-based trawl fishery (largely by medium-size stern-trawlers); stocks in the Bering Sea to the mothership trawl fishery and to large factory-ship trawlers. Trawl fishing in inshore waters has been left to primitive dredgers of various types.

An assessment of the achievements of this system depends on the criteria used. It has contributed greatly to development of an extremely diversified industry, to maximization of total production, and perhaps to maximization of aggregate earnings of fishermen. On the other hand, the system has not been satisfactory for conservation of individual stocks from a biological point of view, nor has it contributed toward increasing productivity of inshore and coastal fisheries.

On the international scene, the licensing system has often been combined with catch limits and other measures as required under international agreements. In the North Pacific, highseas salmon fishing, northern crab fishing, herring fishing off the USSR, and whaling are all subject to national quotas. Usually these are further divided into subquotas among different fisheries for the same species, among different mothership fleets, or sometimes among individual vessels.

USSR

After serious setbacks during and after World War II, systematic expansion of sea fisheries by the USSR started in the late 1940s, and quickened in the 1960s. Large fishing vessels have been constructed according to a few standardized models and the emphasis of the postwar development has been heavily on high seas fisheries, with vessels operating in fleets. Exploratory fishing precedes commercial operations. Fishing vessels are accompanied by factory/motherships, transport vessels, and various service ships. One fleet may consist of more than 100 vessels and each fleet is equipped to process virtually everything in the catch.

Several types of large-scale fishing take place in the North Pacific: inshore salmon fishing; trawl fishing off Kamchatka, in the Bering Sea, off the Aleutians, in the Gulf of Alaska, and in waters farther south; crab fishing mostly in west Kamchatka and partly in other areas; herring fishing along the coast of the Sea of Okhotsk and in the Bering Sea; less important saury and mackerel fishing in waters off the Kurils and northern Japan; and whaling. Other operations, mostly coastal, are of minor importance.

Fisheries in the Pacific Ocean are under the administration of Dalryba (Vladivostok), one of five central administrative bodies in the Ministry of Fisheries. All major high seas fisheries are under state enterprise and are fully controlled. Management measures can be put into effect as need arises.

On a global basis, the relative weight of distant-water fisheries is greater for the USSR than for Japan. In the North Pacific, the USSR operates distant-water fisheries in the eastern Bering Sea and the northeastern Pacific. But she finds herself in the position of a coastal state with respect to fishing by Japan for salmon, crab, herring, and ground-fish along the coasts of Kamchatka, the Kurils, Siberia, and Sakhalin. Her interest in waters near the Japanese Islands is at present limited to saury and mackerel fishing.

USA

As mentioned before, US fishing activities in the North Pacific are concentrated on a relatively small number of species, namely salmon, tuna, crabs, shrimps, and some groundfishes. In terms of values, salmon and tuna are far more important than the others. Next comes crabs (king, dungeness, and tanner crabs) and shrimps (mainly pandalids.) Other fisheries are of minor importance. Except for small catches of halibut and some other species, the abundant resources of groundfishes in the Bering Sea and northeastern Pacific are virtually unused by US fishermen. The resources of pelagic forms, including anchovy, jack mackerel, saury, and squids, also remain largely unutilized. The fishing industry of the Pacific coast has two distinct sectors: coastal fisheries in the north, and the distant-water tuna fishery in the south which operates mostly in waters off the coasts of other countries.

In general, the basic management strategy of the United States is to establish a catch limit for the season for each management unit and to close the season when the limit is reached. The management unit may be small (eg. salmon) or extremely large (eg. tuna). For salmon, restrictions reduce the efficiency of fishing, so that fisheries can accommodate larger numbers of participants.

Systems directly limiting entry to fisheries do not exist in the United States, although the possibility of instituting one for salmon fisheries has been considered for some years. Regulatory authority is divided among individual states, except for fisheries regulated under international agreements through the respective international bodies for which the federal government is responsible.

Canada

The mainstay of the Canadian Pacific fishing industry in British Columbia is salmon. Salmon fishing is conducted in territorial waters except for offshore trolling. Less important are fisheries for halibut and herring. Small amounts of other groundfishes are also caught. The herring fishery suffered a serious setback due to a sudden decline in most of the populations along the British Columbia coast.

There are two major differences between the domestic management systems in Canada and the United States. First, power to regulate fisheries in Canada is largely in the hands of the central government, in contrast with the divided authority in the United States. Second, Canada has recently introduced a limited entry system to the British Columbia salmon fisheries; a detailed account of this new system is given by Campbell (1973).

SOUTH KOREA

Since the Korean War, fishery production of the Republic of Korea has grown rapidly, the total marine catch reaching 930,000 metric tons (820,000 excluding aquatic plants) in 1970. The country has developed a strong tuna longline fishery in the Pacific, the Atlantic, and the Indian oceans, and small distant-water trawl fisheries, but most marine catches are still from waters adjacent to Korea. Resources in these waters, many of which are used by Japan and other neighboring countries, are already exploited intensively. Coastal fisheries are being modernized and shore facilities improved, but total production from nearby waters is unlikely to increase greatly. Much of the apparently large aquaculture potential in inshore waters is still to be developed, although substantial amounts of seaweeds, oysters, and clams are produced.

Fish being the main source of animal protein in Korea, domestic demand is rising rapidly; international markets for fishery products look as good as ever. The country, therefore, aims at further development of distant-water fisheries. Among the most promising are large-scale trawl fishing in northern waters, particularly the Bering Sea and off Kamchatka and the northern Kuril Islands, and skipjack fishing in the western Pacific. Large stern-trawlers are being built in Japan and Korea, and a skipjack fishery based in Korea will start soon.

The system of fishery regulation in Korea was originally developed by the territorial administration of Japan and was not too different from the Japanese system. It is assumed that most of the important fisheries are under a licensing system, but the author has no first-hand information as to how it operates. There has been direct intervention by the government in fishing and marketing through government-supported corporations, including the Korea Marine Industry Development Corporation and the newly established Agriculture and Fishery Development Corportion. Most inshore and coastal fisheries are organized into cooperatives, which in turn form a national federation.

Although there are many uncertainties about the future of South Korean distant-water fisheries, they are likely to become an increasingly important factor in international arrangements for fisheries in the North Pacific.

NORTH KOREA

There is almost no information on recent developments in fisheries of North Korea. Before World War II there was a large sardine purse-seine fishery (for meal and oil) along the northeast coast. It landed over 1 million metric tons in some years, but the catch dropped to nil by 1943, when sardines almost completely disappeared from the east coast. The present total catch of North Korea might be around 0.7 million tons, but this may be in error by a substantial margin. The mainstay of the east coast fishery is probably Alaska pollack. There are some indications that the country has plans to develop distant-water fisheries.

CHINA

Available information concerning the fisheries of China is scanty. Apparently the largest production comes from freshwater aquaculture, mainly for cyprinids; figures up to 6 million metric tons a year have been suggested. Coastal fisheries are conducted largely through communes; the emphasis on state enterprise in fisheries is not great. There has not been any serious attempt to engage in major distant-water fisheries outside of the China Seas region. No information is available on the nation-wide system of fishery management.

When Taiwan was a possession of Japan it served as a base of Japanese fishing operations in the China Seas. It had fairly well-developed coastal and inshore fisheries as well as productive aquaculture. Post-war developments have been rapid and the island now has a highly diversified fishing industry, including the second largest tuna longline fishery in the world. Taiwanese industry has not shown great interest in fishing ventures in the northern North Pacific, although it conducts some trawling operations off West Africa. The regulatory system of Taiwan was originally similar to the Japanese system, but it is perhaps substantially different now.

MEXICO

The mainstay of Mexican fishing on the Pacific coast is the shrimp fishing and processing industry. Fish resources available in waters around Baja California are grossly underutilized. Cooperatives have been given rights to exploit important species, including shrimp, and the management system operates largely through cooperatives.

SUMMARY

The national interests in fisheries, and the philosophies and methodologies of fishery management, differ greatly from nation to nation in this region. Some are capable of conducting large-scale fisheries in any part of the world, while others, for technical or social and economic reasons, conduct fishing only in coastal waters. The fisheries of some nations are under full control by the government, while those of others are controlled only through limited means.

International Fishery Management

The history of international fishery problems in the North Pacific is not as old as that in the North Atlantic, but still dates from the 19th century. International disputes over the fur seal populations in the northern North Pacific started about 20 years after the purchase of Alaska and finally resulted in the 1911 fur seal convention. Problems arising from Japanese fishing activities on Russian territory also date from the late 19th century and resulted in the treaties of 1907 and 1928. The original halibut treaty and Fraser River salmon treaty between the United States and Canada were signed in 1924 and 1930, respectively.

The need for international fishery agreements has increased greatly since World War II and particularly in the last 20 years as fishery development has quickened. As a result, a complex network of fishery conventions and agreements has developed in this region. These include, in chronological order:

The tripartite treaty of 1952 (Canada, Japan, and the United States). *International convention for the High-Seas Fisheries of the North Pacific Ocean.*

The initial nongovernmental agreement between Japan and the People's Republic of China of 1954 (thereafter revised from time to time). *An agreement between a Japanese association and a PRC's association concerning the fisheries of the East China and Yellow seas.*

The Japan-USSR fishery treaty of 1956. *Convention between Japan and the Union of Soviet Socialist Republics concerning fisheries on the high seas of the northwest Pacific Ocean.*

The new fur seal convention of 1957. *Interim convention on the conservation of North Pacific Fur seals.*

The USA—USSR agreement on fishery operations of 1964. *Agreement relating to fishing operations in the northeastern Pacific Ocean.*

The USA—USSR crab agreement of 1964. *Agreement relating to fishing for king crab* (with tanner crab added later, and periodically revised).

The initial USA—Japan crab agreement of 1964. *Agreement regarding king crab fishery in the eastern Bering Sea.* (with tanner crab added later, and periodically revised).

The Japan—South Korea fishery agreement of 1965. *Agreement between Japan and the Republic of Korea regarding fisheries.*

The initial USA—Japan fishing agreement of 1967. *Agreement concerning certain fisheries off the coast of the United States* (periodically rervised).

The initial USA—USSR fishing agreements of 1967. *Agreement on certain fishery problems in the northeastern part of the Pacific Ocean off the coast of the United States* (periodically revised).

The Japan—USSR crab agreement of 1969. *Exchange of letters concerning crab fisheries in the northwest Pacific Ocean (with a protocol), and agreed minutes* (periodically revised).

The USA—Canada fishing agreement of 1970. *Agreement on reciprocal fishing privileges.*

The Canada—USSR fishing agreement of 1971. *Agreement between the Government of Canada and the Government of the Union of Soviet Socialist Republics on cooperation in fisheries in the northeastern Pacific Ocean off the coast of Canada.*

The inter-American tropical tuna convention of 1949 which covers part of the North Pacific. *Convention for the establishment of an inter-American tropical tuna commission.*

The whaling convention of 1946 for the entire world Ocean. *International Whaling Convention.*

There are some characteristics common to nearly all fishery agreements for the North Pacific alone which deserve examination.

AD HOC NATURE OF AGREEMENTS

International fishery agreements in the North Pacific have been developed principally to deal with specific issues rather than as comprehensive agreements to handle international management problems (real or potential) in general. Thus, the pre-war fishery agreements between Japan and Russia (and later USSR) were largely to resolve problems arising from Japanese salmon fishing from the Russian territory—they did not concern high seas fisheries. The fur seal conventions, both pre-war and post-war, have dealt with only one species, and while they have successfully established a unique concept of management, their scope has been limited. The 1956 Japan–Soviet fishery treaty was an immediate result of a unilateral action to control high seas salmon fishing in the northwestern part of the ocean. The constitutional features of this treaty are comprehensive enough to handle any problem in the region, as far as these two nations are concerned, but regulations under the treaty have been applicable only to salmon, crabs, and herring. Furthermore, crab problems were removed for treatment under a new agreement of 1969. This bilateral treaty might be used for dealing with other issues between the two nations in future — for example, management of pollack fishing in the Kamchatka-Kuril area.

The tripartite international North Pacific treaty, based on the abstention principle, was negotiated originally as a means to eliminate or reduce the threat of Japanese fishing for salmon, halibut, and herring in the eastern half of the Pacific. A list of stocks qualifying for abstention has always been the most important part of the agreement. Of the three forms included in the original list, herring has become unimportant, with only the stocks in southern British Columbia remaining on the list. Abstention from high seas halibut fishing by Japan, as provided in the treaty, no longer makes sense, since nonmember countries can (and one actually does) catch halibut legally in the same waters. The International North Pacific Fisheries Commission (INPFC) created under the treaty has expanded its scope somewhat by including discussions on research and stock assessment aspects of king crab, and later tanner crab, in the eastern Bering Sea. But management aspects of crab fishing have been taken away from the commission to be covered under a separate agreement (1964). The commission also does some monitoring for trawl fisheries in the Bering Sea and the northeastern Pacific, but it has refrained from making recommendations except on halibut. Thus, for practical purposes, the treaty continues to exist to maintain the status quo for salmon.

BILATERAL TREATIES

Three sets of bilateral agreements are in effect to regulate crab fisheries in the northern North Pacific: Japan—USSR, Japan—USA, USSR—USA, In one area, the eastern Bering Sea, crab fisheries are regulated by three agreements: in addition to the USSR—USA and the Japan—USA agreements mentioned above, there is a supplementary agreement between Japan and the USSR concerning allocation of fishing grounds (Kasahara 1972).

The Fraser River salmon convention (USA–Canada) is only for management of this salmon system, and the halibut convention (USA–Canada) only for halibut along the coast of the United States and Canada. Even the Japan–South Korea agreement and the nongovernmental agreement between Japan and China fall far short of covering the major fishing activities in the East China Sea and the Yellow Sea. The former sprang from a unilateral jurisdictional claim, and the latter was negotiated to reduce conflicts between Japanese and Chinese fishermen concerning trawl fishing activities, with purse seine regulations added later.

Four recent bilateral fishing agreements (USA–Japan; USA–USSR; USA–Canada; and Canada–USSR) concern problems arising from extended jurisdiction. All of them are specific, and are subject to frequent revision. Agreements of similar nature also exist between the United States and Mexico (1967) and between Japan and Mexico (1968).

UNREGULATED FISHERIES

While the present international fishery management regime consists of a complex network of ad hoc arrangements, some of the largest high seas fisheries in the area which have real or potential international implications are not covered by any of the existing agreements. Most of the trawl fisheries conducted by the USSR, Japan, and South Korea in the Bering Sea, the northeastern Pacific, and off Kamchatka and the north Kurils, are not subject to any international regulation. The present total catch of these fisheries alone is estimated at 3 million metric tons a year. Other large fisheries that are internationally unregulated include herring fisheries conducted by the USSR and Japan in the central and eastern Bering Sea; saury fisheries in the western Pacific by Japan, the USSR, and Korea; mackerel fisheries off northern Japan by Japan and the USSR; and squid fisheries by Japan and South Korea. Furthermore, much of trawl and purse seine fishing in the East China Sea and the Yellow Sea is not internationally regulated except for the activities in the regulatory areas of the Japan–South Korea agreement and the Japan–China agreement. There is no comprehensive China Sea fishery agreement participated in by all parties fishing there. The only international regulations concerning tuna fisheries are those for yellowfin tuna in the eastern tropical Pacific.

Thus, in spite of the various specific agreements for fisheries in the North Pacific, well over 90% of the total catch comes from fisheries currently not subject to international regulation. This by itself may not be considered a serious defect, as most of these fisheries have not yet become difficult international issues. A real problem is the lack of mechanisms for monitoring the status of these fisheries and resources on which they are based, to predict international management problems likely to arise, and to accommodate consultations to resolve them in a timely fashion. Taking pollack fishing as an example, potential international difficulties in Kamchatka and Kuril waters might be handled under the Japan–USSR treaty for these two nations, but there will be no way to accommodate consultations with a third party if it establishes a strong vested interest in pollack fishing in that area. When three parties (Japan, USSR, and South Korea) begin to compete in pollack fishing in the Bering Sea, which is likely, there will be no mechanism to accommodate tripartite consultations. If the United States becomes interested in pollock fishing, which is also a possibility, the situation will become further complicated.

OTHER PROBLEMS

A common feature of most fishery agreements in the North Pacific is their exclusiveness. Except for the tropical tuna and whaling conventions, none of the fishery agreements covering this region are open to new participants. It would require renegotiation of an entire treaty or agreement to make it an open-ended arrangement. The natural outcome of this common feature is that it is almost impossible to deal with new entries within the framework of existing arrangements. This has been manifested in the South Korean entry to salmon fishing in the Bering Sea.

Another shortcoming is that international management problems are usually dealt with after they have become serious. The emphasis of research effort, too, is directly related to the acuteness of specific political problems. For example, while much work is done to discover the effects of trawl fishing on halibut stocks in the eastern Pacific utilized by a longline fishery, little international effort is made to evaluate the status of exploitation of much larger stocks such as pollack or flounders in the eastern Bering Sea. A large amount of pollack is caught by USSR and Japanese fleets in Kamchatka-Kuril waters, but no joint studies have been made of this important resource. This shortcoming is serious because, with modern technology, a large fishery may develop rapidly. New resources may be exploited to a maximum sometimes in two or three years, as has been demonstrated in the North Pacific, the North Atlantic, West Africa, and elsewhere. The concept of management based on time-consuming research is often not practical. Scientists and administrators have yet to find effective ways to cope with contemporary management problems arising from rapid development of fisheries.

Another problem is lack of a uniform system of collecting and analyzing statistical data. Each country fishing in the North Pacific Ocean has a relatively well-developed national statistical system, but each substantially different from the others. Even for stocks jointly exploited by two or more nations in one area, there is often no way of collecting uniform catch and effort data, or comparable biological information, from these countries. As an example, ocean perch stocks in the northeastern Pacific are being fished by four countries, but the forms of catch and effort data exchanged are all different. It is almost impossible to combine these data as a basis for assessing the state of the stocks. In the Bering Sea, the types of data and information collected and made available vary greatly among the nations fishing there. There seems to be no system of data exchange for pollack in the Kamchatka-north Kuril waters.

MERITS OF PRESENT ARRANGEMENTS

The existing international fishery arrangements have some positive aspects. As there is no single set of principles for international management of fisheries, different problems can be handled under different principles. This often leads to an expeditious and pragmatic solution of the immediate problem. The forms of international regulations range from "abstention" to various quota systems combined with limitations on fishing effort, and further to a system of distribution of benefits (fur seals). In most cases, some form of allocation is adopted to accommodate conflicting interests of the parties concerned.

There appears to be a need for a comprehensive open-ended agreement participated in by as many parties as possible. Such an agreement should be designed to absorb most of the existing arrangements while maintaining their merits, to establish an ocean-wide resource monitoring system, and to facilitate coordinated international research on fisheries.

Some Problems of Management and Development in the North Pacific

FLUCTUATIONS IN THE YIELDS OF COASTAL PELAGIC SPECIES

This topic is treated by Nagasaki (1973), largely based on experience in Japan. Catches of major coastal pelagic resources have been subject to violent fluctuations. The question of how to manage fisheries based on these resources has been perplexing to both scientists and administrators, and solutions are yet to be found. Examples in earlier years are: dramatic changes in the catch of sardines (*Sardinops melanosticta*) in Japan and Korea during the 1930s and 1940s; a similar trend in California sardines (*Sarninops caerulea*) on a somewhat smaller scale; a long-term decline in the catch of spawning herring around the island of Hokkaido since the beginning of this century; a decline in the catch of South Sakhalin spawning herring (Kasahara 1961). (Important Asian herring stocks are now found only in areas farther north, mainly the northern Okhotsk Sea, west Kamchatka, and the USSR coast of the Bering Sea.) More recently the catch of British Columbia herring dropped suddenly.

Scientists do not agree as to the causes of decline in Asian sardines and herring. For sardines, it is possible that the initial sharp decline was from natural causes and that heavy fishing pressure prevented the stocks from recovering. In the case of herring, it is likely that a combination of long-term environmental changes and heavy fishing has been responsible for the virtual disappearance of spawning herring from Hokkaido–South Sakhalin waters, and of smaller populations in other areas of the Japan Sea. The British Columbia herring stocks collapsed after a long period in which their abundance was fairly stable. The causes may be revealed as a result of the closure of fishing for fish meal which has been in effect since the decline.

After World War II Japan intensified fishing on other coastal pelagic species including anchovy, mackerel, jack mackerel, saury, squids, and others. All these pelagic stocks have been fished heavily during the last 15–20 years and they have made up the largest part of landings from waters around Japan. But responses to fishing have varied. For example, saury began to be fished intensively by a new type of gear in the early 1950s and the catch rose to high levels in the late 1950s and early 1960s; it has since been declining. The catch of jack mackerel also began to climb in the early 1950s and reached high levels in the early 1960s; it has been on the decline since 1966. The yield of mackerels was stable at a relatively low level until the early 1960s when it started to rise rapidly, the combined catch of two species (mainly *Scomber japonicus* and partly *S.tapeinocephalus*) reaching 1.3 million tons in 1970. Landings of anchovies have been fluctuating within a relatively narrow range, 300,000–450,000 tons per year. The catch of squids (largely common squid) in coastal waters has shown greater fluctuations, ranging from less than 300,000 tons to over 700,000 tons (Kashara 1972).

The causes of these fluctuations are largely unknown and there are no established management strategies to cope with them. The combined catches of a few important species, however, have been at about the same level in the last 15 years. Thus, a practical way of managing coastal pelagic fisheries is to keep the industry versatile in order to take advantage of most abundant species at any one time. This is possible in a country like Japan, where almost any species that can be caught in large quantities is marketable. But even in Japan price fluctuations cause great variations in the value of the landings. For example, the total catch of saury in 1970 was only 85,000 metric tons compared to over half a million tons in 1959, but the value of the catch was the second highest in history because of the high price of saury, which used to be one of the cheapest fishes available. The year 1971 was a poor squid year, but fishermen's earnings were reported good. The ex-vessel price of mackerel decreases sharply at the height of the season, and an increasing proportion of the mackerel catch goes into fishmeal and oil.

POLLOCK IN NORTHERN WATERS

The total catch of pollock in the North Pacific reached 3.3 million metric tons in 1970, including 2.4 million by Japan, 0.7 million by the USSR, and a rough estimate of the North Korean catch. The 1971 figure is perhaps higher. The best fishing areas known are: the eastern Bering Sea; waters off southwest Kamchatka and the northern Kurils; waters around Hokkaido and Sakhalin; and slong the northeast coast of Korea. Pollock also occur in substantial quantities along the east coast of Kamchatka, the northwestern Bering Sea, including the Gulf of Anadyr, and the northern Gulf of Alaska.

While pollock fishing in northern Japan and northeast Korea has been carried out for many years, fishing in the Bering Sea and the Kamchatka–north Kuril area is recent. The Bering Sea catch was less than 100,000 tons in 1962 compared to 1.2 million tons in 1970. The Japanese catch in the Kamchatka–north Kuril area was less than 100,000 metric tons in 1965 compared to 700,000 tons in 1970. The USSR catch, largely in the Kamchatka–north Kuril area also was less than 100,000 tons in 1963 compared to nearly 700,000 tons in 1970. These figures do not include discards, which are substantial in some areas.

The situation in the Bering Sea is reviewed by Pruter (1973). The Japanese trawl fishery first exploited flounder stocks in the eastern Bering Sea, particularly yellowfin sole (*Limanda aspera*). When the *Limanda* stock declined sharply in the early 1960's the emphasis shifted to pollock. Introduction of a mechanized method of processing pollock into frozen blocks of minced meat (surimi) made fishing for this species very profitable. In addition to a number of mothership fleets operating in the Bering Sea for some time, large factory stern-trawlers (up to over 5000 gross tons, with various processing lines aboard) have been put into operation in recent years. The Japanese pollock fishery in the Kamchatka—north Kuril area has been developed by land-based trawlers, most of which are now medium-size stern-trawlers. Their catches are processed on land. A recent development is to process pollock into frozen fillet blocks for marketing in the United States, but the bulk of Japanese pollock catches are still processed into surimi and fish meal.

About 85% of the Japanese catch of demersal species in northern waters (Kamchatka, north Kuril Islands, Bering Sea) is now pollock. But development of pollock fisheries in these waters has been so rapid that there have not been reliable stock assessment studies to determine the condition of the resources. A symposium held in October 1971 indicates the state of research on pollock in Japan (Japanese Society of Scientific Fisheries 1972). Some scientists believe that the abundance of pollock has increased as other heavily-exploited stocks at the same trophic level (principally zooplankton feeders) have been fished down. It is reported, however, that the average size of fish in the southeastern Bering Sea has decreased substantially, resulting in a lower recovery rate of surimi.

As pollock in northern waters now support the most important of all Japanese distant-water fisheries, certain actions appear desirable to avoid possible disaster. These include full assessment of the status of pollock stocks in the Bering Sea and the Kamchatka–north Kuril area; establishment of catch quotas in each of the two regions (in collaboration with the USSR if possible); and possibly reorganization of the industry to make best use of allowable catches. There is a strong possibility that South Korea will expand its pollock fishing in these waters, which will increase fishing pressure further.

EAST CHINA SEA FISHERIES

The East China Sea, including the Yellow Sea, is the oldest and most intensively exploited trawl fishing area in the Far East. The total catch of demersal species is roughly estimated at 1.6 million tons, with China taking the overwhelmingly large portion (Shindo 1968). After World War II, fishing for pelagic species (particularly jack mackerel and mackerel) has become intensive. Most of the important species, such as croakers (sciaenids), cutlassfish (*Trichiurus*), sharp-toothed eel (*Muraenesox*), lizardfishes (*Saurida*), porgies (sparids), China Sea prawn (*Penaeus orientalis*), as well as jack mackerel, are being fished by four countries. They also migrate between coastal and offshore waters and are fished heavily in both.

Judging from catch-per-unit-of-effort data of Japanese fisheries, many of the demersal species show signs of serious overexploitation. The long-established Japanese pair-trawl fishery in this area faces severe economic difficulties (Shindo and Yagi 1970). There is no international agreement involving all countries fishing in the area, and such an agreement is not likely to come into being in the near future. There is no coordination between the regulatory measures taken by different countries except under the Japan—South Korea treaty and a nongovernmental agreement between Japan and China, both of which are of limited scope, covering only activities in certain offshore areas.

MANAGEMENT OF SALMON FISHERIES

From a management point of view, salmon presents special problems. Measures must be taken to protect the freshwater environment and to secure adequate spawners; there are many individual stocks of different characteristics, which necessitates establishment of multiple management units along the coast; and annual runs must be forecast to prepare fisheries in different units for larger or smaller catches and allow sufficient numbers of spawners to go upstream.

Salmon fishing is of great importance to four nations bordering the North Pacific, the United States, Canada, the USSR, and Japan. Most of the important spawning streams are on the coasts of the USSR and North America. Some salmon migrate over wide offshore areas, sometimes more than 2,000 nautical miles in straight line distance. Some of the Asian and North American salmon occupy the same ocean areas, on both sides of the Aleutian chain (see, for example, Margolis et al. 1966; Neave et al. 1967; and Shepard et al. 1968).

Under the present international regulatory regime, fishing by Japan is prohibited in the eastern half of the North Pacific and of the Bering Sea. Fishing by Canada is prohibited in the Bering Sea, so that only United States and Canadian fishermen harvest salmon in their respective coastal waters. Their fisheries are largely within the limits of national jurisdiction, except for some troll fishing conducted on the high seas near the coast (net fishing by United States and Canadian nationals on the high seas is prohibited under domestic laws). The management of salmon stocks in North America has its own problems; they are discussed in detail by Royce (1973). The basic concept of management is the same in the United States and Canada, except that a system of limited entry has recently been instituted in Canada.

The salmon situation is quite different in the western half of the Pacific and of the Bering Sea. After World War II, Japan developed large offshore salmon fisheries by motherships accompanied by catcher boats (gillnetters), and by land-based fishing vessels (gillnetters and longliners). Under the Japan–USSR fishery treaty, these offshore fisheries are controlled through catch quotas and other measures. The quotas are distributed by the Japanese Government among different Japanese fisheries and further among individual fishing vessels (Kasahara 1972). The entire Sea of Okhotsk and large areas off east Kamchatka and the north Kurils are closed to high seas fishing.

This system in the western half of the ocean presents a number of conservation problems. As the origin of salmon in offshore catches is largely unknown, the quantities of fish removed from different spawning stocks cannot be determined. It is difficult to plan allocation of catches to inshore fisheries because offshore fisheries first take the amounts allocated to them, and inshore fisheries may have to be severely restricted in order to leave sufficient numbers of fish for escapement. The division of catch between the two nations has been in favor of Japan. The offshore fisheries also catch substantial amounts of immature salmon, mostly during the summer before the year of spawning. Furthermore, they intercept salmon of North American origin, particularly in years of large runs of Bristol Bay sockeye salmon (*Oncorhynchus nerka*). This has to be taken into account in the management of salmon by the United States, but the number to be taken by the offshore fisheries is hard to predict.

DEVELOPMENT OF NEW RESOURCES

As mentioned above, there are still substantial stocks of traditional species that are not utilized, or are only lightly exploited. Most of them occur in the eastern half of the region. Pelagic resources in the California current system appear particularly abundant (Ahlstrom 1968). There are various reasons for their failure to be developed. For example, although sauries are found in wide areas of the eastern Pacific, Japanese exploratory fishing has so far failed to locate concentrations dense enough to support profitable operations. This may be because of the lack of sharp boundaries in the surface waters. Large concentrations of squids occur in waters off California and exploratory squid fishing is being conducted by Japan, but it is not yet profitable for Japanese fishing vessels to exploit them and market the catches in Japan. The existence of large anchovy stocks in waters off California is well known and a rough estimate of their potential yield is available. The United States, however, has not developed a large anchovy fish meal industry, mainly because of objections from sport fishermen. The apparently abundant stocks of jack mackerel are also not utilized due to lack of markets in the United States. If an anchovy-based fishmeal industry develops, jack mackerel may be used as additional raw material.

In spite of the above, it appears to be only a matter of time for some or all of these resources to be fully developed as the demand for fish continues to increase. Another possible line of development is deep-water trawling. Trawl fishing in some parts of the North Pacific has been conducted in waters to nearly 1000 m. Some grounds have been found even in waters around mid-oceanic islands. No appraisal, however, has been made of the potential total yield from deep water trawling for the North Pacific as a whole.

Another aspect of development is the possibility of utilizing resources of nontraditional species, which occur in great abundance but are difficult to harvest and market economically with known methods. The development of these resources is a continuation of the recent trend to exploit a greater variety of species, but some technological breakthroughs are required to begin large-scale exploitation of these forms. In the Antarctic the USSR has made substantial effort to utilize the krill (*Euphausia superba*), with limited success. In the North Pacific, the existence of large resources of such forms as red crab (*Pleuroncodes*), lanternfishes (myctophids), gonostomatids, and deepsea smelts (bathylagids), is well known. An enormous biomass of bristlemouth (*Cyclothone*) occurs in the tropical Pacific. Some of the larger zooplankters have been utilized in small quantities. These include sergestids and mystids used for human food or animal feeds in Japan. However, no real effort has been made to develop the abundant resources of nontraditional species occurring in this region. These will remain largely resources for the future for some time.

AQUACULTURE

General problems of aquaculture are covered by Pillay (1973). This review touches only briefly on some aspects of aquaculture that are unique to the North Pacific region.

The region includes the two nations most active in aquaculture in the world: — China and Japan. The emphasis and practices of aquaculture differ greatly between the two. In China, most aquaculture is in inland waters with emphasis on a variety of cyprinids. They are largely herbivorous and characterized by rapid growth and a high feed conversion rate; some utilize natural foods to a great extent. They can be raised in most types of impounded water as well as in culture ponds. Most of them can be reproduced artificially and, with good systems of distribution, sufficient supplies of young fish can be maintained to stock reservoirs and ponds in a wide area. These fishes are highly appreciated in China and other areas of the Far East.

No detailed information is available on the status of aquaculture in China as a whole, but there is no question that phenomenal developments have taken place. Numerous bodies of impounded water all over the country are utilized for aquaculture; sophisticated practices have been introduced; hatchery operations and distribution of young, as well as disease control, have improved greatly. Figures up to nearly 6 million metric tons a year have been cited as the possible total production from inland waters, the bulk of it consisting of cyprinids. It appears almost irrelevant to discuss aquaculture in general without having better knowledge of what is going on in China. It is sincerely hoped that such information will become available, for many other countries could benefit from the experience there. Substantial activities also exist in marine aquaculture, largely for bivalves and seaweeds.

Aquaculture in Japan is characterized by diversity of activity and variety of species raised. The type of aquaculture ranges from seaweeds and bivalves to intensive culture of various fishes and invertebrates. The species include the laver (*Porphyra*), wakame (*Undaria*), kelp (*Laminaria*), and other seaweeds; the oyster (*Crassostrea*), scallop (*Pecten*), and pearl oyster (*Pinctada*); the shrimp (*Penaeus*), spiny lobster (*Panulirus*), blue crab (*Neptunus*), and octopus (*Octopus*); the yellowtail (*Seriola*), puffer (*Fugu*), and porgy (*Chrysophrys*); the eel (*Anguilla*), trouts (*Salmo* and *Salvelinus*), and carps (*Cyprinus* and *Carassius*) in freshwater; and other forms.

Only a few species, however, are of substantial economic importance. They are the laver (231,000 tons in 1970), yellowtail (43,000 tons), eel (17,000 tons), oyster (26,000 tons in meat weight or 191,000 tons with shell), wakame (76,000 tons), carps (19,000 tons), trouts (11,000 tons) and pearl. Kuruma shrimp (*Penaeus japonicus*) culture is widely known, but production is only about 300 tons a year.

Nearly all aquaculture for fishes and invertebrates, in both sea water and fresh water, is carried out by intensive feeding. Usually fishes (largely coastal pelagic species) and fish meal are the main animal protein components of feeds. On a round weight basis, the quantity of feed fish required for yellowtail and eel culture is perhaps seven to eight times the amount of fish produced. The amount of fish meal used for raising fishes may exceed 100,000 tons a year, equivalent to half a million tons in live weight. Fish culture in Japan is obviously a means to produce high-priced products and not to increase the total supply of animal protein from waters. Aquaculture of the two most important fish species, the eel and yellowtail, has a serious weakness in that the young have to be collected from natural waters. The domestic supply of young eels is declining and a substantial quantity is now being imported (Kasahara 1972).

Japan is also a focus of marine pollution problems. Aside from the well-known cases of intensive mercury pollution, which caused the "Minamata disease," many of the productive bays and estuaries suffer from a growing amount of industrial pollution. Examples are Suruga Bay, Ise/Mikawa/Atsumi bays, the Seto Inland Sea, and the Sea of Ariake. All of these shallow waters have been productive areas for aquaculture and inshore fishing, but are seriously threatened by increasing pollution from industrial developments, causing a decrease in productivity and contamination of the products. The frequency of red tides has also increased significantly in recent years.

If the present trend continues it will not be long before some of these, and other inshore areas of Japan, become completely unproductive for aquaculture and inshore fishing. Japan is a test case for man's determination and ability to preserve the shallow seawater environment for aquaculture and fisheries in a highly industrialized country.

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Long-Term and Short-Term Fluctuations in the Catches of Coastal Pelagic Fisheries Around Japan[1]

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Although the total landings of coastal pelagic fishes around Japan have been fairly stable for 10 years, the catch of individual species has shown violent fluctuations. The catch of Hokkaido herring and the sardine is decreasing and shows no signs of recovery. The catch of saury has also decreased sharply since 1960, but that of mackerel has increased substantially. There are big yearly fluctuations in the landings of squid, horse-mackerel, and anchovy, but no consistent trend either way has been shown. Apparently the great variations in stock abundance relate to the hydrographic complex in the waters around Japan. As most of the important coastal pelagic fishes spawn and spend their early life in the area of the continental shelf of the southern half of the Japanese islands, the location and the strength of the Kuroshio current play an important role in the ever-changing environmental conditions. Although the causes of these fluctuations are largely unknown, they can be classified as long, intermediate and short-term. The large-scale fluctuation over a long term, as in the case of the Hokkaido herring and the sardine, may possibly be due to evacuation of the main spawning grounds. The intermediate period of fluctuation is caused by the degree of survival of the young. A variety of causes must be responsible for the short-term fluctuation, including survival, for which there is no consistent trend, and the effect of the Kuroshio current on the distribution of the young fish.

Bien que le total des captures de poissons pélagiques côtiers des eaux japonaises demeure assez stable depuis 10 ans, on observe des fluctuations considérables dans les prises de certaines espèces. Les captures de harengs de Hokkaido et de sardines diminuent sans qu'aucun signe de redressement ne se manifeste. Les prises de balaous ont elles aussi fortement régressé depuis 1960, tandis que celles de maquereaux se sont notablement accrues. On constate de grandes fluctuations annuelles dans les quantités débarquées d'encornets, de chinchards et d'anchois, mais sans tendance cohérente nette. Selon toute apparence, les fortes variations de l'abondance des stocks sont liées au complexe hydrographique des eaux japonaises. Etant donné que la plupart des importantes espèces pélagiques côtières se reproduisent et passent la première partie de leur existence sur le plateau continental de la moitié sud des îles japonaises, la situation et la force du Kouro-Shivo jouent un grand rôle dans les conditions écologiques en constante évolution. Bien que leurs causes soient en grande mesure inconnues, on peut distinguer trois types de fluctuations: à long terme, à moyen terme et à court terme. Les grandes fluctuations à long terme, comme dans le cas du hareng de Hokkaido et de la sardine, sont peut-être dues à l'abandon des principaux lieux de reproduction. Les fluctuations à moyen terme sont en rapport avec le taux de survie des alevins. Enfin, s'agissant des fluctuations à court terme, divers facteurs entrent en jeu, notamment le taux de survie — sans tendance cohérente observable — et les incidences du Kouro-Shivo sur la distribution des jeunes poissons.

Aunque la totalidad de los desembarques de pesca pelágica costera del Japón han sido bastante estables durante 10 años, la captura de especies determinadas ha sufrido violentas fluctuaciones. Las de arenque y de sardina de Hokkaido decrece y no muestra signos de recuperación. Las de papardas también han descendido vertiginosamente desde 1960, pero las de caballa han aumentado considerablemente. Hay grandes fluctuaciones anuales de los desembarques de calamares, jureles y anchoas sin que exista una tendencia consistente en ningún sentido. Aparentemente las grandes variaciones de la abundancia están relacionadas con la complejidad hidrográfica de las aguas costeras del Japón. Como la mayoría de las especies pelágicas costera más importantes transcurren su temprana edad y desovan en la plataforma continental de la mitad sur de las islas del Japón, la situación e intensidad de la corriente Kurosivo desempeña un papel importante en las condiciones ambientales en continuo cambio. Aunque las causas de estas fluctuaciones son, en gran parte, desconocidas, pueden clasificarse de mucha, mediana y corta duración. La grande de mucha duración como sucede en el caso del arenque y la sardina de Hokkaido puede deberse a la evacuación de los principales

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lugares de desove. La fluctuación mediana la origina el grado de supervivencia de los jóvenes. La fluctuación corta puede deberse a muchas causes, incluyendo la supervivencia, para la que no hay una tendencia consistente y los efectos del Kurosivo en la distribución de los jóvenes.

Catch of Coastal Pelagic Fish near Japan

PRODUCTION by the offshore and the coastal fisheries (defined by size of boat used and not by location of fishing grounds) of Japan depends on the biological productivity of the waters and on fishing effort. Because of extensive and intensive fishing in Japanese waters with many types of gear, it may be reasonably accepted that landings of a species closely reflect its availability. The catch[2] from Japanese waters can be divided into four groups: (1) Coastal pelagic fishes, including herring, sardines, round herring, anchovies, mackerel, horsemackerel, saury (included here despite wide distribution), yellowtail, Spanish mackerel, mullet, dolphinfish, flyingfish, squids, and miscellaneous postlarval fish (mostly anchovies); (2) Demersal fishes, including flounders, cod, pollock, Atka mackerel, rockfishes, sandfish, argentines, croakers, conger eels, hairtails, sea breams, sandlance, cuttlefish, octopus, shrimps, and crabs; (3) The littoral or neritic species, including various kinds of shellfish, sea weeds, sea cucumbers, and sea urchins; (4) Species not included in the above groups, including highly migratory fishes such as the tunas, skipjack, and salmon, and various miscellaneous fish in small numbers.

Annual catches by group from 1958 to 1969 are shown in Table 1. The total annual landings from coastal waters range from 4.2 million (1958) to 5.1 million tons (1968), of which 86 to 90% consist of groups 1 to 3. Group 4, ranging from 10 to 14% of the catch, is eliminated from consideration because of the highly migratory nature of the tunas and skipjack, arbitrary catch limits for salmon, inclusion of foreign-caught fish, and lack of statistics by species for the miscellaneous fish. The total of groups 1 to 3 ranges from 3.7 million tons (1958) to 4.5 million (1968). The percentages of each group to the total are also shown in the table: group 1 from 56 to 61% (51% for 1964 is exceptional), group 2 from 25 to 28% (34% for 1964 is exceptional) and group 3 from 14 to 16%. These figures indicate a rather stable composition by group, despite annual variations in total catch. Looking back through

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[2] All statistical figures are from annual statistics of the Ministry of Agriculture and Forestry, Japanese Government.

TABLE 1. Catch by group of the coastal fisheries around Japan, in thousands of metric tons. Figures in parentheses are percentages.

Year	Group 1	Group 2	Group 3	Total of Groups 1–3 (A)	Total of coastal and offshore (B)	Ratio: (A)/(B)
1958	2273 (60)	927 (25)	576 (15)	3776	4220	0.89
1959	2381 (60)	1037 (26)	572 (14)	3988	4443	0.90
1960	2304 (58)	1068 (27)	605 (15)	3977	4407	0.90
1961	2401 (58)	1102 (27)	600 (15)	4103	4586	0.89
1962	2567 (60)	1084 (25)	646 (15)	4297	4772	0.90
1963	2429 (58)	1133 (27)	639 (15)	4201	4709	0.89
1964	1932 (51)	1297 (34)	565 (15)	3794	4255	0.89
1965	2424 (59)	1118 (27)	576 (14)	4118	4648	0.88
1966	2344 (58)	1083 (27)	627 (15)	4054	4645	0.87
1967	2365 (56)	1182 (28)	652 (16)	4199	4837	0.87
1968	2758 (61)	1141 (25)	607 (14)	4506	5161	0.87
1969	2504 (60)	1058 (25)	596 (15)	4158	4809	0.86

TABLE 2. Rank of landings for major pelagic fishes.

Species	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	Order
Mackerel	5	5	3	4	4	2	2	1	1	1	1	1	1
Squid	3	2	2	3	1	1	3	4	4	2	2	2	2
Horsemackerel	4	3	1	1	2	3	1	2	2	3	4	4	3
Anchovy	2	4	4	5	5	5	4	3	3	4	3	3	4
Saury	1	1	5	2	3	4	5	5	5	5	5	5	5
Sardine	6	6	6	6	6	6	8	8	8	8	8	8	6
Yellowfish	8	8	8	7	7	7	6	6	6	6	6	6	7
Round herring	7	7	7	8	8	8	7	7	7	7	7	7	8

the statistics to 1910, it can be seen that the fisheries depended heavily on group 3 in the early days, with the catch of pelagic fish increasing later. When the sardine catch reached an unprecedented high level of 1.6 million tons in 1936, the total catch of group 1 was around 2.1 million tons, which is comparable to the recent catch of this group. The utilization of demersal fish has been the slowest to develop, probably because the sophisticated gears required were not available until later.

The catch of group 1, including important pelagic fish, has not fluctuated greatly in the past ten years. Within the group, however, the species composition has continued to change remarkably in a short period. Sardine and herring, which predominated several decades ago, have declined to a low level, and the trend is downward. The landings from 1958 to 1969 for the eight most important species are shown in Table 2.

Saury, first in 1958 and 1959, has decreased rather sharply since 1960, the 1969 landings being only one-ninth of the 1958 catch. Horsemackerel, mostly landed in southern Japan, was first in 1960, 1961, and 1964. The catch of this species amounted to about 600,000 tons in 1960 but has gradually decreased to some 290,000 tons in 1969. Mackerel was fifth in 1958 and 1959 but landings have gradually increased throughout the past 10 years. Since 1965, this species has predominated in the coastal landings, exceeding a million tons in 1968 and 1969, which amounts to about 40% of the total catch of groups 1 to 3. Squids have shown greatest year-to-year fluctuation, without any consistent trend either way. They were first in 1962 and 1963. Anchovies have maintained a fairly high level throughout the period, although the year-to-year fluctuation is not small. The final column of the table shows the overall placing by species, the order being mackerel first, followed by squids, horsemackerel, anchovies and sauries.

The fluctuation in the catch of the important coastal pelagic fishes is a direct cause of instability in the coastal fisheries. Because the biological mechanisms of changing abundance in relation to environmental changes is largely unknown, despite the continuing efforts of fisheries biologists, it is almost impossible to predict the catch for any species even in the immediate future. In view of the general belief that large fluctuations in stock size occur from natural causes, the impact of fishing on the stock is considered to be much smaller or even completely insignificant. Therefore, except for a few cases, particularly of longer-living fish, limiting the catch or restricting fishing effort would probably be useless as a means of stabilizing production at a high level. On the other hand, increased fishing effort is not likely to result in a substantial increase of catch or a reasonable profit. There is no doubt that the same degree of fluctuation would occur as in the past. However, it is expected that the total catch of coastal pelagic fishes around Japan will be maintained at a fairly stable level unless there is a drastic change in fishing effort.

Areas of Reproduction and of Harvest

OCEAN CURRENTS

The waters adjacent to Japan can be divided into four areas: the Kuroshio, the Oyashio, coastal waters, and the Tsushima. The waters around Japan are greatly influenced by the warm Kuroshio current (a sector of the oceanic circulation in the Pacific) originating off the Philippines. This current moves northeastward from Taiwan along the ridge of the continental shelf off China. South of southern Japan it runs at a maximum velocity of 160–180 cm/sec. The main Kuroshio current runs no more than 140 km from shore. A counter-current, which flows outside the main current to the southwest, has a maximum velocity of 20 cm/sec. South of Kyushu a branch of the current flows into the Sea of Japan through the Korean Strait and forms the Tsushima Current. The main Kuroshio current then runs due east along the Pacific coast of Honshu, crossing the South Honshu Ridge. Here its flow pattern changes and results in the hydrographic complex in the coastal waters there (Uda 1949). Between the Kuroshio main current and the land masses are the coastal waters which lie in a narrow west-east stretch. They are strongly influenced by the Kuroshio current. The Kuroshio extensions to the north meet the cold water of the Oyashio current that flows south along the Kuril Islands and the northeastern coast of Honshu. In the convergent area there is a complicated boundary with a number of eddies that vary in position seasonally and from year to year, in response to location and strength of the two major currents. The cold current, after sinking under the warm current, forms the Oyashio under-current. This from time to time upwells and forms a cold water mass along the coastal area. In the Sea of Japan the Tsushima current, carrying water of high temperature and salinity, runs northward along the coast of Japan, while the waters in the northern part of the sea, cooled sharply in winter, sink under the warm current.

BIOLOGICAL PRODUCTION

In the Oyashio area the standing crop of phytoplankton amounts to 10^4–10^6 cells/liter, in the Kuroshio main current the figure is 10^2–10^3 cells. The standing crop in the coastal waters on the Pacific side is estimated to be 10^3–10^4 cells. In the Sea of Japan 10^4–10^6 cells have been observed in the northern part, but the crop decreases gradually to the south. The biomass of zooplankton in the upper 100 m in the Oysahio region is usually less than 50 mg/m^3 on the oceanic side, but more than 100 mg/m^3 on the neritic side. Generally of less than 50 mg/m^3 is found in the Oyashio region in winter, but a remarkable increase occurs in summer, sometimes up to 250–500 mg/m^3, especially east of Hokkaido (Fukuda 1970).

SPAWNING REGIONS

Because of the mixing of the warm and cold currents, the waters around Japan favor fish reproduction despite the limited extent of the continental shelf. Most of the abundant pelagic animals, such as sardines, anchovies, mackerel, sauries, squids and yellowtail, spawn and spend their early life in temperate waters under strong influence of the Kuroshio. Evidently, these pelagic fish, except sauries, spawn in coastal waters (or on the coastal side of the Kuroshio). Surveys show that the grounds are confined to the region of the continental shelf. Sardines from the egg to postlarval stages are most abundant within 20 miles of shore, gradually decreasing out to 30 miles offshore (Kondo 1964).

Anchovy spawning occurs in various places within the more neritic waters. The distribution of this species throughout its life is also within the coastal waters. Mackerel also spawn in continental shelf waters, not deeper than 200 m (Usami 1968). Eggs and larvae of horsemackerel are mostly found in a long band of waters on the neritic side of the Kuroshio main current, but not beyond the edge of the continental shelf. Most squid spawn in waters southwest of Kyushu within the Tsushima area, where the continental shelf is wide. The saury spawning area extends out broadly on the Pacific side, covering not only the coastal waters but also the more oceanic part outside the main Kuroshio current (in a strict sense, therefore, sauries should not be included among the "coastal" pelagic fishes).

MOVEMENTS OF YOUNG FISH

Since the spawning areas of these fish are located to the south of their feeding grounds, the waters west of Chiba Prefecture (141°E, 35°N) on the Pacific side and south of Noto Peninsula (135°E, 37°N) on the Japan Sea side are vitally important for reproduction of these fish. However, these waters are directly or indirectly influenced by the ceaseless and complex movements of the Kuroshio and the Tsushima currents, and any given set of conditions may work in favor of some species but against others. Two features of the Kuroshio current vary, the volume of transport and the location of its axis. The volume of transport section varies greatly, with significant increases in spring and autumn. The location of the axis and its meandering may be related to the occurrence of the cold water mass, which apparently has an influence on the mortality rate of young fish.

EARLY MORTALITY

Young fish (egg to postlarvae) are carried to the north, the Kuroshio and the Tsushima currents playing important roles in this movement. It is generally thought that the mortality of young fish due to dispersion and limited availability of food must be high in early stages of development. It is estimated, for instance, that 70% of sardine eggs may die before hatching (2 or 3 days) and 96.5% in the 2 weeks before they have grown to 5.3 mm (early postlarva). Over 99.9% may be lost before they reach 17 mm — about 58 days (Nakai and Hattori 1962). Rearing experiments indicate that sardine young can tolerate a wide range of temperature and salinity, but are extremely vulnerable to shortage of food (Kondo 1964). Copepod naupliis, the most important food for larval fish, are usually found abundantly in waters close to shore but are less abundant in the offshore Kuroshio current. The feeding rate of larvae is apparently high where copepod naupliis are abundant, and fatness of the larvae is significantly greater in the coastal waters than offshore. Observations from 1955 to 1962 off Shizuoka Prefecture (Pacific side) indicate that the standing crop of macroplankton is small when a cold water mass develops and is greater when the extent of the cold water mass is limited (Honjo et al. 1966).

FISHING AREAS

Young hatched out in temperate waters gradually spread to the north as they grow, even going north of the polar front if more food is available there. Thus, the usual situation for pelagic fishes is that the area for harvest is north of that used for reproduction, although the spawning grounds for some species also form important fishing grounds. Large quantities of sauries, mackerel, and squid are caught off Sanriku district, the northeastern part of Honshu, and off Hokkaido on the Pacific side. The location of good fishing grounds differs from species to species, as do the best seasons. But most of the fishing grounds, except for sauries, are in the area of the continental shelf.

Fluctuations in Landings

Any stock of fish is more or less subject to fluctuations, the more violent fluctuations usually being observed among pelagic rather than demersal fishes. As landings do not necessarily reflect abundance of fish, more dependable abundance indices, such as catch per unit of effort, should be used. However, fishing in the vicinity of Japan is so intensive that the total landings may closely reflect abundance of the commercial pelagic fishes.

Although causes of fluctuations are largely unknown, they can be classified as long-term, intermediate, and short-term.

Large-scale fluctuations over the longer term (sometimes several decades or more) are sometimes characterized by complete disappearance of the fish from their main spawning grounds, as has been observed for the Hokkaido herring and sardine stocks around Japan. When a spawning stock in a given area disappears, it may take a rather long time to recover even if environmental conditions become favorable.

The size of a stock of fish may vary in relation to survival rate of the young. When survival is good for a number of years, the stock can be maintained at a high level. A poor survival rate means a low level of stock. Recent decreases and increases in the landings of sauries and mackerel may be considered as intermediate-term fluctuations.

Apart from decreases or increases over a number of years, stock size fluctuates from year to year or in similar short periods. A variety of causes must be responsible for this type of fluctuation, among which survival rate must play a major role. If the survival rate varies year after year at random, without any consistent trend — as is the case of squids around Japan — stock abundance is likely to be maintained at about the same level, with yearly fluctuations.

HOKKAIDO HERRING

The Hokkaido herring fishery landed about 975,000 tons annually at the end of the last century and was supported by the "spring herring" stock that moves in to shore for spawning from late March to late May. Herring were caught by set nets along the coast, and the fishing season overlapped the spawning season. According to fragmentary local records some substantial fisheries were operating in southern Hokkaido in the middle of the seventeenth century. The herring migrated further south throughout the eighteenth and nineteenth centuries, when their distribution included the northern half of Honshu. From time to time there was poor fishing in some limited areas. Records of total herring landings have been available since 1871. During the 30 or so years after that date the herring fishery achieved the height of its prosperity, landing 600,000 to 700,000 tons every year. The fishing grounds were extended northward, and along the coast of the Sea of Okhotsk. This tremendous development was possible because of an increase in fishing effort and because of the abundance of herring.

Landings decreased gradually after 1900, with short-term fluctuations. Some recovery was observed from 1913 to 1927, when 500,000 tons a year were caught on average. Then the downward trend was resumed until in 1938 the catch was as low as 12,000 tons. It improved somewhat in the 1940s, but declined again to lower levels, and by 1960 the catch was less than 300 tons. The once huge fishery is virtually extinct, and there has been no sign of recovery of the stock. The decline was caused by the disappearance of spawning runs, beginning in the south and extending northward along the west coast of Hokkaido. Disappearance of spawning runs was first observed at the northern tip of Honshu around 1900. Next, around 1910, the southern spawning grounds on the west coast of Hokkaido were evacuated. At about the same time, the herring catch declined in the southern part of Korea. The south Sakhalin spring herring declined from 1931 onward.

Many theories have been put forth as to the causes of the depletion of the Hokkaido spring herring. The gradual disappearance from southern spawning grounds seems to have been a widespread phenomenon on the Asian coast of the North Pacific. Depletion of the stock was obviously a result of continuous failure of recruitment, but the primary reason is not clear. There may have been failure to occupy spawning grounds because of adverse environmental factors, or massive mortality of the young. Whatever the reason, long-term environmental changes have in fact occurred over a wide area of the Northwest Pacific. A rise in the temperature of the sea off the west coast of Hokkaido from 1910 onward has been reported by many scientists (Motoda and Hirano 1963). The consistent warming of the sea in this region was accompanied by various biological events, such as the appearance of warm water species in the northern area and damage to the cold water algae. While it is still an assumption, it appears that the progressive abandonment of spawning grounds from south to north was caused, directly or indirectly, by the warming of the sea water.

Apart from the long-term fluctuation, there have been some intermediate-term fluctuations in this herring stock. In the 48-year period from 1907 to 1955, catches (as defined by Hanamura (1963) in 4 years were large (more than 4 milliard (10^9) fish), 12 were medium (1–4 milliard), and 32 were small (less than 1 milliard). The total catch during the 48 years amounted to 56.5 milliard fish, of which 34.9% were from large, 45.3% from medium, and 19.8% from small catches. Before 1921 large and medium catches occurred frequently so that a high level was maintained. From 1921 onward, catches were mostly in the small category.

SARDINES

Annual sardine landings in Japan rarely exceeded the level of 200,000 tons until 1912. Subsequently, the catch increased steadily, with minor year-to-year fluctuations. In 1929 more than 700,000 tons were taken. In 1930 landings jumped to 1,000,000 tons, and then increased rapidly to 1,600,000 in 1936. Then the reverse trend started, and from 1940 to 1945 landings dropped to 160,000 tons. After the war, they increased to 400,000 to 500,000 tons, only to decline to less than 30,000 tons in the late 1960s. During the height of this fishery, from 1925 to 1940, the fish were distributed widely all over the Asian coasts, including Korea, the Maritime Province of the USSR, and Sakhalin. The sardine fishery in Korea started in 1923 and the catch increased rapidly to 1,400,000 tons in 1937, but then declined sharply until 1944 when the fishery almost disappeared. Exactly the same trend was observed in the Maritime Province and in Sakhalin. In the prosperous years there were 5 spawning grounds along Japan — south of Kyushu, east of Kyushu, and off Boso Peninsula on the Pacific side, and west of Kyushu and off Noto Peninsula on the Japan Sea side. Naki (1955) estimated that 70% of the total spawning was to the south of Kyushu, which probably supported the tremendous numbers of sardines widely distributed in the east Asian region. The drastic depletion of sardine stocks in various parts of the region occurred at exactly the same time, probably linked with the sharp decrease of the spawning stock south of Kyushu.

Sardine larvae from the south of Kyushu drifted northeast in the Kuroshio current. Nakai collected many postlarvae in the waters off Kyushu in the spring of 1941, but almost none a little further west where an extensive cold water mass was located. On the basis of this finding he speculated that almost all larvae from south of Kyushu might have been caught in the turbulence between warm and cold water masses and lost. This may explain why the spawning stock in the south of Kyushu decreased to 9% in 1947 and to less than 1% in 1948.

Fragmentary records concerning sardine fishing, dating from about the middle of the seventeenth century, seem to indicate that a good fishing period appears once every 100 years or so (Ito 1961). However, the poor fishing periods, as estimated from the old records, may not have been as poor as those of recent years.

Since the depletion of the main stock, the Japanese sardine fishery has depended on several local stocks which have been subject to considerable fluctuation. The spawning grounds of these stocks are located farther north than the old grounds. The water temperature in the old grounds was 18–20C and eggs hatched in about 36 hr. More recently, spawning has been in waters of 14–17C and the eggs require more than 50 hr to hatch (Kondo 1964).

MACKEREL

There are two species of mackerel. The common mackerel *Scomber japonicus* is distributed widely around Japan. The "goma" mackerel, *Scomber tapeinocephalus*, is distributed in warmer waters, mostly in the western part of Japan and the East China Sea. Distribution of these two species overlaps in southwestern waters. As it is not easy to separate them, landings are combined. However, it is apparent that the relative importance of goma mackerel has decreased.

Total landings of mackerel in Japan have steadily increased since 1910 when 30,000 to 40,000 tons were caught in a year. In 1939 about 150,000 tons were landed. After a sharp drop during the war, the catch jumped to 290,000 tons in 1954 and over 670,000 tons in 1965. In 1968 and 1969 landings exceeded 1,000,000 tons. The steady increase in total catch is largely due to increased fishing intensity. However, abundance of common mackerel on the Pacific side has increased since the late 1950s. In particular, the spawning stock off the Izu and Boso Peninsula has increased greatly since 1961. According to an abundance index in terms of catch per man-night, the stock there has almost tripled from 1961 to 1966. Fish of this origin are caught abundantly in waters off eastern Honshu and Hokkaido at the age of 2 to 3. On the Japan Sea side there are two stocks, one of which spawns around Noto Peninsula and the other west of Kyushu and in the East China Sea.

SAURY

In view of their wide distribution in the subarctic area across the Pacific, sauries are not really coastal fish. The fishing grounds covered by Japanese vessels are west of 150°E, where there are two stocks, autumn spawning and spring spawning. Most of the catch is landed at Sanriku and Hokkaido from August to November. The fishing grounds are in convergent waters between the south-bound cold and the north-bound warm currents. Because of complicated hydrographic conditions in the converging waters, location of fishing grounds varies from season to season and year to year: sometimes the grounds are in coastal waters and sometimes offshore. Such variations apparently caused the fluctuations in saury landings observed early in the fishery. Up to 1910 fishing was done with purse seines within 12–15 miles of the shores of Boso Peninsula and Shikoku Island. These are southwest of the present fishing grounds. Driftnets replaced seines in the 1920s and the fishery extended northward and offshore. After the second world war the driftnets were replaced by stick-held lift nets and lamps for a few years. Since then the new fishery has increased rapidly both in amount of fishing effort and in the extent of the fishing grounds.

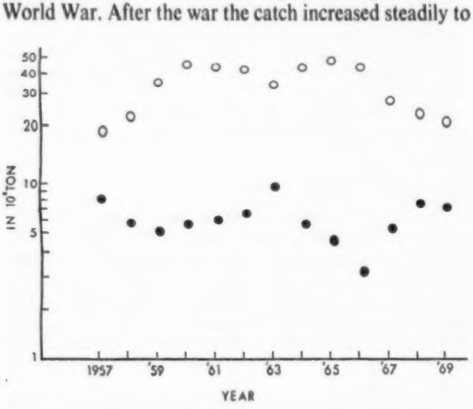

FIG. 1. Recent trend of landings of five major species, in units of 10,000 metric tons.

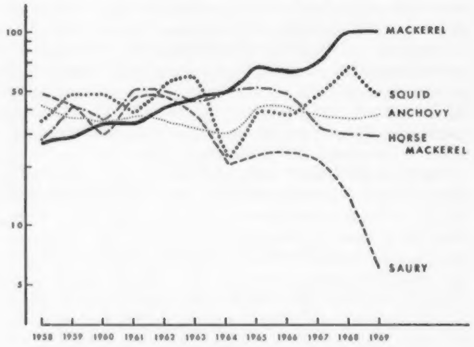

FIG. 2. Horsemackerel catches on the Japan Sea side (open circles) and the Pacific side (closed circles), from 1957 to 1969.

The annual landings from the beginning of this century show maxima about 1912, in 1925, and during the second World War. After the war the catch increased steadily to 575,000 tons in 1958; then it decreased gradually from 1960, dropping to the low level of 63,000 tons in 1969. If these peaks and troughs reflect stock abundance, an increase can be expected in the near future. Before the recent decline, scientists were of the opinion that saury stocks must be more stable than those of any other pelagic fish because their spawning takes place over a wider area and for a longer season. The cause of the recent persistent decline is not yet known. Soviet scientists have suggested that the decline must be from reproduction failure (Fisheries Agency, Japan 1970). A significant cooling of the sea waters was observed in the spawning area in 1963, when many dead eggs and larvae were collected. However, in view of wide distribution of eggs and larvae and the highly pelagic nature of this species, a long-term fluctuation caused by evacuation of spawning grounds seems hardly likely to occur.

HORSEMACKEREL

The main spawning ground of this species is located in the southern part of the East China Sea along the 200- m contour. There are several other small spawning groups in both the Japan Sea and on the Pacific side. The spawning season extends from January to May, moving from south to north as the season progresses. However, most spawning takes place from February to March. Due to the location of the main spawning grounds, most of the eggs and larvae are carried by currents toward the Japan Sea, resulting in a greater catch there. About 5,000,000 tons of horsemackerel were landed during the 12 years from 1958 to 1969, more than 80% from the Japan Sea side. In the annual catch, however, there is the reciprocal relation, so that when the Japan Sea catch is larger than the current average, the Pacific catch is smaller. The cause of this apparently lies in the surface water temperatures. If these are lower in early spring (March) in waters immediately south of Kyushu, landings from the Japan Sea that year will be smaller and those from the Pacific larger. This suggests that distribution of eggs and larvae by the currents, reflecting perhaps the influence of, or reasons for, the water temperature change, affects distribution of the stock. As the catch from the Japan Sea is much greater than that taken on the Pacific side, the total horsemackerel catch declines in a cold year, such as in 1957 and 1963.

Summary

The depletion of herring and sardines was caused by environmental changes: warming of the sea water over many years, for herring; and untimely occurrence of cold water mass over shorter periods, for sardines.

The sharp increase in sardine abundance starting in the 1920s might be related to the gradual disappearance of herring. Later, sardines declined sharply when the main spawning grounds south of Kyushu Islands were abandoned. This might have been caused by mass mortality of postlarvae in a cold water mass on the nursery grounds, but little spawning has been observed there since a rise in water temperature. It may take a long time for the main spawning grounds to be reoccupied by sardines, even if favorable conditions continue to prevail. The declines of sardines and herring may result from cyclic fluctuations, but if so, the period of fluctuation is too long to make realistic predictions about possible recovery.

The increased mackerel landings reflect an increase in abundance. The stocks in the Japan Sea are in fairly good condition and may even be increasing.

Reasons for the decline in saury catches are not known, although failure of reproduction because of cooling water may be a cause.

For horsemackerel, surface water temperature may be a principal influence controlling abundance and catches.

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Korea: A Case Study in Promoting Development Through Fishermen's Training[1]

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KOH, Y. H. 1973. Korea: a case study in promoting development through fishermen's training. J. Fish. Res. Board Can. 30: 2368–2372.

The recovery of Korea as a fishing country is one of the most significant recent developments in fisheries. Disappearance of the sardines, and the impact of the second world war and Korean war, ruined the country's fishing industry. The Government of the Republic of Korea decided in the early 1960s to develop a deep-sea fishing industry, especially for tuna. The success of this enterprise is measured by the rise in the deep-sea catch from 657 metric tons in 1962 to 82,782 metric tons in 1969.

One important factor in this successful development was the training scheme set up by the Government with the aid of the United Nations Development Program and the Food and Agriculture Organization. Training was essential because the country lacked captains, mates, engineers, and other technicians to operate the additional deep-sea fishing vessels.

The traditional fishery educational institutes produced large numbers of graduates, but these had little practical training. The UNDP/FAO scheme, however, concentrated on practical training. The trainees were carefully selected to ensure their suitability and determination to take up fishing as a career. The thoroughness and effectiveness of the training is evidenced by the fact that all the 761 officers trained to date are employed on fishing boats.

In view of the success of the deep-sea training scheme a similar project was established for training men in the coastal fisheries. The UNDP and FAO also assisted in this project. It has contributed officers to both the inshore and deep-sea fleets.

La reprise opérée par le Corée sur le plan halieutique est l'un des exemples récents les plus frappants du développement des pêches. La disparition des sardines, le retentissement de la deuxième guerre mondiale et les effets de la guerre de Corée avaient ruiné l'industrie nationale de la pêche. Le Gouvernement de la République de Corée a décidé de mettre sur pied, au début des années soixante, une industrie de la pêche hauturière, notamment pour le thon. L'augmentation des prises en haute mer, qui sont passées de 657 tonnes métriques en 1962 à 82,782 tonnes métriques en 1969 témoigne du succès de cette entreprise.

Ce succès est imputable dans une large mesure au système de formation instauré par le Gouvernement avec l'aide du Programme des Nations Unies pour le Développement et l'Organisation des Nations Unies pour l'alimentation et l'agriculture. Cette formation s'imposait, car le pays manquait de capitaines, d'officiers, de mécaniciens et d'autres techniciens pour utiliser les navires supplémentaires de pêche hauturière.

Les nombreux diplômés formés par les traditionnels instituts d'enseignement halieutique ayant des connaissances pratiques insuffisantes, le Programme PNUD/FAO s'est surtout attaché à dispenser une formation pratique. Les stagiaires ont été soigneusement choisis pour s'assurer qu'ils étaient aptes et décidés à embrasser la carrière de pêcheur. A preuve du caractère approfondi et de l'efficacité de cette formation, la totalité des 761 officiers formés à ce jour travaillent à bord de bateaux de pêche.

Devant le succès du programme de formation à la pêche en haute mer, un projet analogue a été institué pour la formation de spécialistes de la pêche côtière. Le PNUD et la FAO ont également prêté leur concours à ce projet, qui a permis d'affecter des officiers aux flottilles de pêche côtière et hauturière.

La recuperación experimentada por Corea en cuanto a país pesquero constituye uno de los recientes acontecimientos de mayor importancia en las pesquerías. La desaparición de las sardinas y las repercusiones de la segunda guerra mundial y la de Corea arruinaron la industria pesquera del país. El Gobierno de la República de Corea decidió perfeccionar su industria pesquera de altura a principios del decenio de 1960,

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en especial, en lo que al atún se refiere. El éxito de esta empresa puede medirse por el aumento de las capturas en alta mar que pasaron de 657 toneladas métricas en 1962 a 82,782 toneladas métricas en 1969.

Un factor muy importante en este acontecimiento fue el plan de enseñanza instituido por el Gobierno con ayuda del Programa de las Naciones Unidas para el Desarrollo y la Organización de las Naciones Unidas para la Agricultura y la Alimentación. La enseñanza fue esencial debido a que el país no contaba con capitanes, pilotos, maquinistas y otros técnicos que pudieran utilizar los pesqueros de gran altura.

Los institutos de enseñanza pesquera tradicionales proporcionaron gran número de graduados pero con poca preparación práctica, a la que se dedicó el plan PNUD/FAO. Los alumnos fueron cuidadosamente seleccionados con objeto de que por su idoneidad y determinación hicieran de la pesca una carrera. La efectividad y minuciosidad de la enseñanza queda demostrada por el hecho de que la totalidad de los 761 oficiales que han cursado los estudios hasta la fecha han tenido empleo en embarcaciones de pesca.

En vista del éxito del plan de enseñanza de pesca de altura, se instituyó un proyecto similar para enseñar la pesca costera. Este proyecto también recibe la ayuda del PNUD y de la FAO. Ha formado oficiales para las flotas pesqueras de alta mar y costeras.

SCHOOLS which train fishermen, especially officers of vessels, can play an important role in developing a fishing industry, but few countries have organized such schools. Japan is one exception, having a long history in fisheries education. She established her first fisheries school in 1899, and now has 53 fishery high schools providing 3-year courses and six fishery colleges providing 4-year courses. One leading Japanese fishing company has its own training center, providing a 1-year course free of charge.

The United States of America, a leading fishery country, has neither colleges nor high schools for training officers or fishermen, nor is there a fishing officer's certificate system. Thus, American fishermen have no formal training in their trade, but learn it by experience on boats. Recently the United States Government tried to improve fishermen's skills through extension services.

The United Kingdom, one of the leading trawl-fishing countries, does not have colleges or high schools training fishing vessel officers, although experienced fishermen in that country can take courses on navigation or electronics at special schools and obtain a certificate.

Norway has only recently established fishing schools where experienced fishermen can study advanced fishing technology.

Fishermen's schools are becoming a necessity as modern fishing vessels and operations become complex and sophisticated. Korea is a country where formal training of fishermen has been a significant factor in accelerating development of the fishing industry. The country has developed a large industry in a relatively short time, as a result of determined efforts to provide capital, technical skills, and trained manpower.

Korea Fishing Industry

Korea is a peninsula where cold and warm currents mix off the eastern seaboard; it has an extensive continental shelf off the western coast (Yellow Sea and East China Sea). This gift of nature for developing a fishing industry has provided an economic asset as well as a rich source of protein for the people.

Although Korea was once a leading fish-producing country (Table 1), disappearance of the sardine (*Sardinops melanostica*), the second world war, and the Korean war reduced the industry to a primitive state, and it was not until the early 1960s that the modern Korean fishing industry began to develop. Following successful exploratory cruises in the 1950s for tuna in the Pacific and Indian oceans, the Government put emphasis on developing a deep-sea fishing industry based on tuna longline vessels. Arrangements to provide capital investment for fisheries development were included in the Government's first Five-Year Economic Development Plan (1962–67).

TABLE 1. Landings of fishery products in Korea, 1927–45, and of South Korea, 1946–71, with production goals for 1972–76 (in metric tons). (The catch shown after 1945 refers only to South Korea.)

Year	Metric tons	Year	Metric tons
1927	813,662	1952	281,849
1928	860,647	1953	266,995
1929	946,383	1954	254,642
1930	866,693	1955	265,895
1931	1,044,982	1956	346,561
1932	1,073,212	1957	409,309
1933	987,133	1958	403,304
1934	1,375,172	1959	392,060
1935	1,491,942	1960	357,181
1936	1,668,616	1961	447,634
1937	2,127,851	1962	470,187
1938	1,760,969	1963	532,153
1939	2,046,717	1964	599,824
1940	1,727,888	1965	636,512
1941	—	1966	702,295
1942	—	1967	750,349
1943	—	1968	852,291
1944	295,747	1969	862,784
1945	228,188	1970	935,462
1946	296,346	1971	1,073,733
1947	301,952	1972	1,096,252
1948	289,147	1973	1,211,302
1949	290,204	1974	1,331,035
1950	219,450	1975	1,383,686
1951	266,849	1976	1,456,956

[a] Source: 1927–49: Statistics of Fisheries Catches (Fish. Res. and Dev. Agency) 1961; 1950–70: Yearbook of Fisheries Statistics (Office of Fisheries). 1970; 1972–76: Production Goals, Third Five-Year Economic Development Plan (Office of Fisheries).

TABLE 2. Development of the deep-sea fishing industry, including projections to 1976.[a]

	Deep-sea catches (1000 metric tons)			Export	Deep-sea fleet		No. of	
Year	Total	Export	Domestic use	$ Millions (U.S.)	No.	Total tonnage (1000 gross tons)	foreign bases	No. of crew
1957	Experimental fishing			–	1	0.1	–	25
1958	0.3	0.3	–	0.1	1	0.1	1	25
1959	0.5	0.5	–	0.1	3	0.4	1	76
1960	0.9	0.9	–	0.3	3	0.4	1	76
1961	0.4	0.4	–	0.1	1	0.1	1	56
1962	0.7	0.7	–	0.2	5	0.6	1	127
1963	2.6	2.6	–	0.6	10	1.3	2	281
1964	2.6	2.6	–	0.8	20	3.0	3	536
1965	8.6	8.6	–	2.6	65	10.9	4	1,760
1966	26.8	26.8	–	9.1	138	31.6	8	3,632
1967	40.5	40.5	–	12.5	180	41.0	12	4,210
1968	50.0	47.7	2.3	15.5	210	51.7	12	5,056
1969	82.7	71.7	11.0	24.0	224	70.5	15	5,718
1970	89.6	72.4	17.2	37.6	278	75.8	14	6,972
1971	159.3	90.8	68.5	55.1	351	109.3	15	9,103
1972	233.0	130.0	103.0	74.0	396	133.3	15	11,329
1973	287.4	184.4	103.0	101.6	454	164.7	16	13,233
1974	336.5	233.5	103.0	126.5	506	193.1	17	14,941
1975	395.9	292.9	103.0	155.9	566	225.9	18	16,929
1976	460.2	357.2	103.0	186.9	633	263.9	19	19,029

[a] Source: Present status of Korean deep-sea fishing (June 30, 1972), Bureau of Fisheries Promotion, Office of Fisheries.

The total catch from Korean coastal waters in 1962 was 448,117 metric tons, which was increased by 64% in 7 years to 691,348 metric tons (Table 2). During the same period the deep-sea catch increased 126 times, from 657 in 1962 to 82,782 metric tons in 1969. Exports of fish caught by deep-sea vessels increased by 60 times, to $37,663,000 (US) in 1970, starting from $625,000 (US) in 1962. During this time exports of the coastal fisheries increased 3.3 times, from $9,302,000 (US) (1963) to $30,593,000 (US) (1970).

Thus from 1961 to 1971 Korea established a position as a leading deep-sea fishing nation, in 1971 ranking 15th, with a catch of 1,074,000 metric tons. The Government plans to increase production of marine products still further. The Third Five-Year Development Plan (1972–76) has set up a production target of 1.5 million metric tons by 1976, with exports valued at $200 million (US).

This impressive development of the deep-sea fishing industry was made possible by the rapid expansion of the distant-water fleet. By February 1972 this consisted of 298 tuna longliners, 60 stern trawlers, and 8 carrier vessels, mostly operating from foreign fishing bases.

In the early stages of implementing the planned expansion of the fishing industry, the Government provided assistance for the construction and purchase of vessels. But one obstacle quickly became apparent: the lack of fishermen skilled and experienced in distant-water fishing. Korean fishermen operated mostly in small-scale coastal fishing, using traditional boats and methods, and captains, mates, engineers, and radio operators for the new vessels were hard to find.

A misconception in many developing countries is that a modern fishing industry can be developed simply if sufficient capital can be made available. Korean leaders did not realize that commercial fishing is complex, requiring technicians skilled in engineering, electricity, electronics, fishing technology, etc. Consequently, the Government engines, fish finders, radio direction finders, and communication equipment, without training fishermen in their use and maintenance. Much of the equipment soon became inoperable, and many of the new, expensive vessels lay idle for extended periods for lack of qualified crews or because of breakdowns due to poor maintenance. It was therefore realized that the fisheries development program must include training.

Training

HISTORY

As it happened, Korea already possessed fishery educational institutions, mostly set up during the Japanese occupation. These now include 10 high schools, four junior colleges, and two fishery colleges. These schools produce a large number of graduates every year, and there should have been no shortage of deep-sea fishing officers and technicians. Among the reasons why such a shortage did exist was Government neglect of manpower requirements in development plans. But perhaps the most pertinent reason is that the curricula at the colleges and schools (set by the Ministry of Education) have no direct relation to problems of the fishing industry.

The fishery schools were established by the Japanese and offered courses in fishing technology, processing and aquaculture. These ceased operation during the second world war, after which they were reopened, but most of their facilities and equipment had been damaged or destroyed and there were few qualified instructors. Theory courses in fishing technology were given, but these offered little or no practical instruction. When the writer was a student at a Korean fishery college, the subject of fishing gear and methods was studied in the classroom, and practical training was limited to a short period aboard a coastal fishing boat as an apprentice. He was treated as a guest and could only observe fishing operations. Although most fishery schools had their own training vessels, only limited funds were available to operate them for training. Even when they operated, they were used primarily for oceanographic observations or navigation practice.

The facilities and equipment of the 16 fishery educational institutions in Korea have gradually improved, but their curricula are still based more on theory than on practical application. Fisheries education is styled after the Japanese system and is usually taught by teachers educated in Japan. Although this system may be appropriate for highly developed fisheries of Japan, it is not suitable for the much less developed Korean fishing industry. Moreover, many of the students are not particularly motivated to a career in fisheries, and many enrol because they cannot get into a normal academic school.

Many of these men might be accepted by the industry if they acquired practical experience or were given on-the-job training after completing their formal education, but since all Korean students are obligated to serve three years in military service after graduation from high school or college, many never get this opportunity, and this alone causes a high loss to the industry. Many who may want to go fishing return to civilian life and cannot find jobs because vessel owners cannot risk engaging untried crew members, particularly on distant-water vessels. These men, therefore, find employment in other fields and few graduates enter the fishing industry.

NEW POLICIES

This was the situation in the early sixties when the Government embarked on a vigorous policy of developing the fishing industry. A major effort had to be made to provide skilled manpower.

The procedures for this kind of operation involve the following activities: (a) Establish a fishing training center. This should be geared to produce trained personnel in a short period. The scope and level of training will depend on local conditions and the projected needs of the expanding industry; (b) Set an educational standard. Since the training is of short duration, there is not sufficient time to teach academic subjects, so that trainees should already have an education, the level of which will depend on the training courses offered; (c) Select candidates intent on fishing. The trainees should be single men who have completed military service and have a desire to join the fishing fleet immediately on completing the training course; (d) Concentrate on practical training, especially at sea. Lectures should be limited to basic theory for understanding the professional subjects, and for a certificate examination; (e) Provide the training free. All trainees should be accommodated at the center without charge, with all expenses provided by the Government or industry; usually the students come from poor families.

The important problem is to gear the fishery education system to relate closely to the needs of the industry. In Korea, the Ministry of Agriculture and Forestry decided that the existing vocational fishing training was not effective, and a new Training Center would have to be established. The Government applied for assistance from the United Nations Development Program. In 1965 the UNDP/ROK Deep-Sea Fishing Training Center was established, with FAO as the executing agency.

Two courses of study were given: fishing technology and marine engineering. Trainees were selected from young men with a high school education who had completed their military service. The duration of the courses was originally set at 12 months and the curricula were limited to subjects concerned with fishing vessel operations. Trainees were boarded at the Center under a semi-military style of discipline, an arrangement which was aimed at helping the trainees to cope with the hard life at sea. Training included the operation of fishing vessels, and experience in commanding a crew.

During the first 5 months training was on shore. Four hours' instruction in the morning was given on basic theory and terminology, and 3 hr in the afternoon on practical instruction in workshops. For the next 6 months trainees worked as crew aboard a training vessel, operated on a semi-commercial basis under the supervision of the FAO Masterfisherman. The vessel spent almost the entire 6 months at sea, giving the trainees an opportunity to learn how to operate the vessel, to construct and repair gear, to use fish-finding apparatus, and to deal with fish handling and freezing. After completing their sea duty the trainees took a certificate examination given by the Ministry of Transport. Those who passed were assured of employment as officers on deep-sea fishing vessels.

All expenses of training are paid by the Government, including uniforms, textbooks and a small allowance. The local operating costs of the Training Center are met by the Government, while UNDP pays cost of training equipment, vessels and expert services.

When the Fishing Training Center Project first started there was little response from young men, despite widespread publicity. Indeed, one of the most difficult aspects of developing Korea's modern fishing industry has been to locate men willing to be trained to operate the sophisticated vessels and equipment of the new fleets. There are more than a million fishermen in Korea fishing with traditional methods and equipment but it is difficult to encourage them to enter a training program. Many have family responsibilities so that they cannot afford to take the time for training. Most have grown up in the artisanal fisheries where short trips are the rule, so they are reluctant to take employment on a vessel that may be away for 2 or 3 years at a time.

The training program has therefore been directed to young men with some formal education and without family responsibilities. Preference is given to candidates who have some fishing experience. Fishing is not an attractive career for young men unless considerable incentives are offered. In Korea, these include nearly certain job oppor-

TABLE 3. Value of exports of fishery products by countries (1971).[a]

$ million (U.S.)									
Japan	Peru	Korea	USA	USSR	U.K.	France	Thailand	Yugoslavia	Italy
342	220	114	97.6	84.9	37.7	27.3	15.3	8.4	8.1

[a]Source: The statistics of fisheries products export (FAO).

tunities in a rapidly developing industry, and valuable certificates for those who pass the examination. For a less sophisticated type training program in the coastal fishery an incentive could be in the form of loans for the purchase of engines, winches and other equipment. It was not long after the Center opened that it became known that jobs on fishing vessels were readily available and that wages were higher than in other fields, and many more applications for training began to be received. As jobs for educated men are scarce in Korea, many of them were attracted to fishing. There are now five applicants for every place available. The 761 young officers who have completed this training are all employed in deep-sea fishing boats and have earned a good reputation.

Following the success of the deep-sea fishing training project, the Government requested a similar project for the coastal fisheries. This was organized in the same way, with financial help from UNDP and with operational supervision by FAO. The project assists in modernizing the coastal fishing industry by increasing the fishermen's knowledge of and skill in handling modern fishing equipment. The trainees must have had at least 2 years' sea experience. The training period is 6 months and covers fishing technology and marine engineering. A large percentage of these trainees have taken jobs in deep-sea fishing vessels as junior officers. By so doing they earn much higher wages than they could in coastal fishing boats.

Results of a Training Program

The fishery training centers have played a significant role in the development of Korea's fishing industry. From 1957 to 1961 there were fewer than 100 deep-sea fishermen in Korea. Distant water fishing began in earnest in 1962, five tuna boats employing 127 fishermen. By 1966 the tuna fleet had increased to 138, employing 3632 fishermen. Five years later, the number of boats had increased to 351, employing more than 9000 fishermen so that Korea now ranks 15th in landings and third in exports of fish products (Table 3).

By 1971 a total of 657 trainees were at work on 327 deep-sea fishing vessels, an average of two graduates per vessel.

The success in tuna longlining and stern trawling has prompted the Government of Korea to enter another deep-sea fishery, that of the western Pacific skipjack tuna. A considerable investment is being planned to provide a modern pole and line fleet, involving local and foreign capital. As this is an entirely new fishery for Korea, the Training Center's facilities are being expanded, with UNDP and FAO assistance, to include specialized training for this enterprise.

The Ministry of Education and the old-style fishery schools are now becoming aware of the effectiveness of the type of fishing training offered at the new Center and the Ministry recently arranged a special seminar for the principals of fishery educational institutions to review the present fisheries educational system. As a result, 14 fishing and engineering instructors have been attached to the Training Center for special training to improve their techniques in teaching fishing methods and engineering.

The success of the ROK/UNDP/FAO projects has become so well known that 13 foreign trainees from eight countries have enrolled for the courses. A number of training institutions patterned partly on Korea's have been established in other countries where fishing industries are being developed or expanded.

Table 4 shows the value of deep-sea exports, the increase in the number of vessels, and of trainees. It is not meant to imply that all credit for the development of the fishing industry goes to the training program, but it is a fact that the trainees have played an important role in developing the industry.

TABLE 4. Korean exports of fishery products caught by deep-sea boats, number of deep-sea vessels operating, and cumulative number of graduates from the ROK/UNDP/FAO Fishing Training Center.

Year	Value of exports of fishery products $ Million (U.S.)	No. of deep-sea vessels in operation	Cumulative no. of graduates from training centre
1962	0.2	5	0
1963	0.8	10	0
1964	0.8	20	0
1965	2.6	65	0
1966	9.1	138	76
1967	12.5	180	212
1968	15.5	210	255
1969	24.0	224	410
1970	37.6	278	550
1971	55.1	327	657

The Government has indicated its continued support to the fishing industry through the Third Five-Year Economic Development Plan (1972–1976). The Plan provides for increasing the number of deep-sea fishing vessels to 633 and of deep-sea fishermen and officers to 19,029 by 1976. The training project must continue to operate, and it must maintain its present quality and output.

Development and Present Status of Bottomfish Resources in the Bering Sea[1]

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PRUTER, A. T. 1973. Development and present status of bottomfish resources in the Bering Sea. J. Fish. Res. Board Can. 30: 2373–2385.

Fisheries for bottomfish in the Bering Sea are largely a post-second world war development, with landings having increased from 13,000 metric tons in 1954 to an estimated 2 million metric tons in 1971. Most of the harvest is off Alaska in the southeastern sector of the Bering Sea, where conditions are most favorable for development of resources and fisheries. In 1970 and 1971, Japan accounted for approximately 84% and the USSR 15% of the combined harvest by all nations. South Korea, United States, and Canada took the remaining 1% of the harvest. Initial target of the fisheries of Japan and USSR was yellowfin sole. Yields of yellowfin sole were not sustained and Japan shifted attention to Alaska pollock. Production of Alaska pollock in 1970 from the North Pacific (about half is from the Bering Sea) was tied with Atlantic cod for second place in worldwide landings of a single species.

Analysis of condition of resources is handicapped by unavailability of adequate statistics for earlier years of the fishery. Even for those participants who provided detailed statistics, information is usually lacking on quantities of fish discarded, and changes in fishing gear and fishing tactics that need to be corrected for in assessing the condition of stocks. There is no institutional mechanism for Bering Sea or the North Pacific that makes it mandatory for all nations to provide common and comprehensive statistics on their fisheries and to undertake joint management.

Consideration of available data suggests that the pulse nature of the Bering Sea fisheries resulted in the depletion of several important resources. Yellowfin sole were overfished during the early period of the fishery. Although the picture is far from clear for other species, the Pacific Ocean perch, blackcod, and shrimp resources also appear to have been overfished at least on certain important grounds within the Bering Sea. The chronology of Japan's fishery for herring suggests the initial exploitation of the stock in the western Bering Sea off Asia may have been intense enough to deplete that resource. Although there is yet no indication of depletion of Alaska pollock, the great increase in harvest of that species, coupled with reliance on a few year classes to support the fishery, should serve as a warning against further uncontrolled increases in fishing.

La pêche aux poissons de fond dans la mer de Béring s'est surtout développée après la deuxième guerre mondiale et le total des quantités débarquées est passé de 13,000 tonnes en 1954 à 2 millions de tonnes (estimation) en 1971. L'essentiel des captures se fait au large de l'Alaska dans le secteur sud-est de la mer de Béring où règnent les conditions les plus favorables au développement des ressources et à celui des pêches. En 1970 et 1971, la part du Japon dans le total des prises mondiales a atteint environ 84% et celle de l'U.R.S.S., 15%. La Corée du Sud, les Etats-Unis et le Canada se sont partagé le restant soit 1%. L'objectif initial des pêcheries japonaises et soviétiques était la sole à nageoires jaunes. Mais les rendements n'étaient pas constants et le Japon a préféré de tourner vers la morue du Pacifique occidental. En 1970, la production de cette espèce dans le Pacifique Nord (environ la moitié des captures provient de la mer de Béring) venait à égalité avec la morue de l'Atlantique, au deuxième rang de la liste mondiale par espèces des quantités débarquées.

On ne dispose pas de statistiques suffisantes pour les premières années de cette pêche, aussi est-il difficile d'analyser l'état des ressources. Même les participants qui fournissent des statistiques détaillées ne donnent généralement pas de renseignements sur les quantités de poisson rejetées, ni sur les modifications des engins et des tactiques de pêche en conséquence desquelles il faut prévoir une correction dans l'évaluation de l'état des stocks. Il n'y a pas pour la mer de Béring ou pour le Pacifique Nord de mécanisme institutionnel qui prescrive à toutes les nations de fournir des statistiques communes et complètes sur leurs pêches et d'entreprendre conjointement l'aménagement des ressources.

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

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L'examen des données disponibles fait penser que le rythme régulier des opérations de pêche dans la mer de Béring a entraîné l'épuisement de plusieurs ressources importantes. La sole à nageoires jaunes a été surexploitée au cours de la période initiale. Bien que le tableau soit loin d'être clair pour d'autres espèces, il semble aussi que les ressources en *Sebastodes alutus*, morue charbonnière et crevettes aient été trop intensément pêchées, du moins sur certains fonds importants de la mer de Béring. L'historique de la pêche au hareng entreprise par le Japon fait penser que les opérations initiales sur ce stock dans la partie occidentale de la mer de Béring, au large de l'Asie, ont peut-être été suffisamment intenses pour épuiser également cette ressource. Il n'y a encore aucun indice de raréfaction de la morue du Pacifique occidental, mais l'accroissement considérable des captures, associé au fait que l'on compte sur quelques classes d'âge pour alimenter la pêche, devrait servir d'avertissement contre de nouvelles intensifications non contrôlées des activités.

La pesca de especies demersales en el mar de Bering, en gran parte, ha tenido lugar después de la segunda guerra mundial, habiendo pasado las descargas de 13,000 toneladas métricas en 1954 a 2 millones de toneladas métricas, según estimaciones, en 1971. La mayor parte de las capturas se realizan frente a Alaska, en el sector sudeste del mar de Bering, donde las condiciones son favorabilísimas para la pesca. En 1970 y 1971, Japón obtuvo, aproximadamente, el 84%; la U.R.S.S. el 15% de toda la pesca. El restante 1% se distribuyó entre Corea del Sur, Estados Unidos y Canadá. El objetivo inicial de las pesquerías japonesas y rusas era el lenguado de aleta amarilla. Los rendimientos de esta especie no se mantuvieron y el Japón se dedicó a la pesca del abadejo de Alaska. En 1970 la pesca de abadejo de Alaska del Pacífico Norte (aproximadamente la mitad se captura en el mar de Bering) igualó a la del bacalao del Atlántico ocupando el segundo lugar en las descargas mundiales por especies.

El análisis de las condiciones de los recursos lo dificulta la falta de estadísticas adecuadas correspondientes a los primeros años de las pesquerías. Incluso aquellos participantes que facilitaron estadísticas detalladas, dieron una información incompleta con respecto a las cantidades de pescado desechado, los cambios en el equipo y métodos de pesca y que tienen que hacerse al evaluar la condición de las poblaciones. No existe una institución para el mar de Bering o para el Pacífico Norte que obligue a todas las naciones a facilitar estadísticas completas y comunes de sus pesquerías y para emprender una reglamentación conjunta.

El estudio de los datos indican que la naturaleza de la pesca en el mar de Bering ha dado por resultado el agotamiento de diversos recursos importantes. Durante la primera fase se abusó de la pesca del lenguado de aleta amarilla. Aunque el panorama dista mucho de estar claro, por lo que a otras especies se refiere, los recursos de gallineta, paleros y camarones del Océano Pacífico también muestran los efectos de una pesca abusiva, por lo menos, en algunos caladeros importantes del mar de Bering. La cronología de las pesquerías japonesas del arenque indican que la explotación inicial de las poblaciones situadas en el oeste del mar de Bering, frente a Asia, ha debido ser lo suficientemente intensa para agotar el recurso. Aunque no existan indicios todavía del agotamiento del abadejo de Alaska, el gran aumento de las capturas de estas especies, unido a contar con unas pocas clases anuales para sustentar a las pesquerías, ha de servir como advertencia contra otros aumentos indiscriminados de la pesca.

THIS paper reviews what is known of the production and status of major bottomfish resources in the Bering Sea. Herring and shrimp are included because their fisheries are conducted as an adjunct to those for bottomfish. While development of the Bering Sea fisheries can be traced farily well, the status of the resources is more difficult to determine. The major difficulty in determining the status of the resources is the unavailability to the author of adequate statistics on the early development of the fisheries.

The most comprehensive source of data on fisheries in the Bering Sea is the International North Pacific Fisheries Commission (INPFC), whose publications and files contain detailed records on the fisheries of Japan, Canada, and the United States. My conclusions on the status of resources are, therefore, mostly based on an examination of INPFC records and primarily on those from Japan, which accounts for over 80% of the combined harvest by all nations of bottomfish in the Bering Sea.

Description of the Bering Sea

The Bering Sea is a vast area bounded on the south by the Aleutian Islands, on the west by Siberia and the Kamchatka Peninsula, on the east by Alaska, and on the north by the Arctic Ocean.

Ice closes off many fishing grounds in the Bering Sea; sea ice reaches its maximum extent in February, when it usually covers most of the surface, except in clear areas around the southern portion of the deep ocean basin, and the Western Alaska Peninsula and Aleutian Island area. In August and September there generally is no ice in the Bering Sea and open water exists north of Bering Strait.

The potential of the bottomfish resources in the Bering Sea is somewhat indicated by the extent of its continental shelf, which is among the largest in the world's seas. It amounts to about 1,000,000 km^2, approximately 20% more than the combined shelf areas of the Seas of Okhotsk and Japan. The shelf is broadest in the eastern and central sectors, where in some places it extends some 600 km from shore. It is narrowest south of Cape Navarin off Siberia and off Kamchatka, where the average width is 50–60 km.

Within the Bering Sea the general pattern of water circulation is cyclonic. Gyral conditions are common, especially in the eastern shelf region, and play a major role in creating stable conditions which favor development of fish and shellfish populations. These gyrals also influence development of "cold spots," which are avoided by many fishes. The variable positions of the gyrals from year to year, and from season to season, result in changing location of the cold spots with consequent changes in the distribution of fishes, especially flatfishes (Natarov 1963). These changes are of great practical importance to fishing fleets. Relatively warm temperatures in the southeastern Bering Sea create a favorable winter habitat for many fishes.

Most of the Bering Sea shelf is rich in benthos, with the highest biomass occurring on grounds covered by colder waters (Neiman 1963). Although the largest biomass occurs in the northern cold water region, the situation is different in regard to the availability of benthos as food. Most of the northern sector, where biomass is highest, is relatively inaccessible to bottomfish because of below zero water most of the year. Within this cold water region is about 80% of the total benthos biomass. Within the remainder of the Bering Sea, about two-thirds of the biomass is in the southeast sector off Alaska (Neiman 1963). Moiseev (1964) concluded that in terms of food values the eastern Bering Sea is the most favorable region in the entire North Pacific for growth of flatfishes and other benthic organisms such as crabs and shrimps.

Consideration of all factors (climatological, geological, hydrographical, and biological) leads one to conclude that the optimum conditions for development of bottomfish resources and fisheries are in the eastern, and particularly the southeastern, sector of the Bering Sea. As will be shown, this conclusion is supported by the historical development of the fisheries.

Development of Fisheries

Sea mammals — not fish — were the incentive for the initial exploitation of Bering Sea resources in the 18th and 19th centuries. Some knowledge of fish and shellfish resources was obtained incidental to the early hunting of sea otters, fur seals, and whales, but it was not until the late 1800s, when United States vessels began fishing the Bering Sea cod banks, that the first commercial venture for bottomfish was begun. This fishery for Pacific cod (*Gadus macrocephalus*) in the southeastern Bering Sea was fairly intense throughout the period 1905–15 and fishing was conducted there by United States vessels until the early 1950s (Alverson et al. 1964). Halibut (*Hippoglossus stenolepis*) were reported as being present in the Bering Sea by United States cod vessels as early as the 1880s. However, halibut did not reach North American markets from the Bering Sea until 1928 (Thompson and Freeman 1930). Small and infrequent landings of halibut were made by United States and Canadian vessels between 1928 and 1950 and catches were not landed every year until 1952 (Dunlop et al. 1964). Present participation by North American nationals in fisheries for bottomfish is limited to a small longline fishery for halibut by United States and Canadian fishermen in the eastern Bering Sea and around the Aleutian Islands. There is also a small subsistence fishery for herring (*Clupea harengus pallasi*) by Alaskan natives at scattered places along the coast.

Although Japan's exploratory trawlers made limited surveys of bottomfish resources in the Bering Sea as early as 1929–31, the first truly commercial operations were not carried out by Japan until 1933–37. This initial trawling venture by Japan was for fish meal and oil. It was followed by trawling in 1940–41 for frozen fish to be used as human food. Both the fish meal and frozen fish operations were off Alaska in the southeastern Bering Sea. Total production from the five years of the fish meal operations is given by Kibesaki (1965) as 121,000 metric tons (mt). Production of the frozen fish in 1940–41 is not known to the author; however, it probably did not exceed 40,000 mt. Thus, pre-World War II production by Japan of bottomfish from the Bering Sea amounted to less than 200,000 mt.

Japan did not resume her bottomfish operations in the Bering Sea until 1954. Harvest by Japan of bottomfish, herring, and shrimps (*Pandalus borealis*) grew to over 600,000 mt in 1961, declined to around 300,000 mt in 1963, and thereafter increased to a level of about 1¾ million mt in 1971. The decline in catches between 1961 and 1963 was caused by overfishing of yellowfin sole (*Limanda aspera*) by the combined efforts of Japan and the USSR; the great increase after 1963 resulted from a shift to Alaska pollock (*Theragra chalcogrammus*) as Japan's primary target species.

Most of Japan's harvest of bottomfish is by mothership fleets and by independent trawlers. A land-based dragnet fishery ("hokutensen") also harvests substantial amounts of bottomfish from the Bering Sea, but is only licensed to fish in waters west of 170°W longitude. Catches of bottomfish, herring, and shrimp by Japan's fisheries in the Bering Sea in 1970 are shown below by type of fishery; and the area of operations, and total catches in Fig. 1.

	Landings (metric tons)
Mothership	1,162,000
Independent trawlers	263,000
Land-based dragnet	54,000
Longline–gillnet	2,300
Total	1,481,300

The USSR first carried out exploratory surveys in the Bering Sea for bottomfish in 1931–35. Similar surveys were again made in 1951–55. Most of this work was in the western Bering Sea adjacent to the coast of the Soviet Union; however, some was in the eastern Bering Sea (Moiseev 1963). Beginning in 1958 the USSR carried out extensive surveys with most of the effort being concentrated in the eastern Bering Sea. USSR fishing fleets first appeared in the eastern Bering Sea in 1959 and by 1963 their area of operation extended off much of Alaska's vast coastline, from the Bering Sea through the Gulf of Alaska and along the Aleutian Islands (Chitwood 1969).

Primary targets of Soviet fisheries in the eastern Bering Sea have been flatfishes, Pacific ocean perch (*Sebastes alutus*), and herring. All are harvested with trawls, in contrast to Japan's fisheries which utilize a variety of fishing gear including stern and pair trawlers, Danish seiners, longliners, and gillnetters. Annual catches by Soviet vessels operating in the eastern Bering Sea ranged from 100,000 to 300,000 mt in recent years.

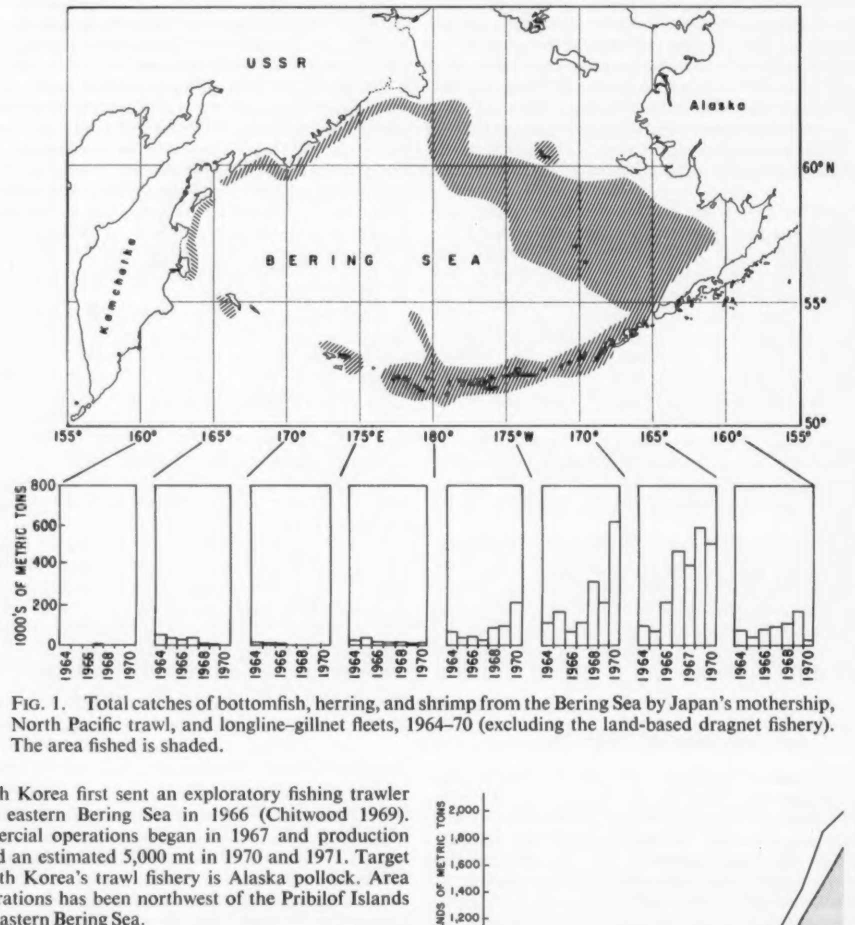

FIG. 1. Total catches of bottomfish, herring, and shrimp from the Bering Sea by Japan's mothership, North Pacific trawl, and longline–gillnet fleets, 1964–70 (excluding the land-based dragnet fishery). The area fished is shaded.

South Korea first sent an exploratory fishing trawler to the eastern Bering Sea in 1966 (Chitwood 1969). Commercial operations began in 1967 and production reached an estimated 5,000 mt in 1970 and 1971. Target of South Korea's trawl fishery is Alaska pollock. Area of operations has been northwest of the Pribilof Islands in the eastern Bering Sea.

The nature of operations by North American fishermen is different from that of Asian and Soviet fishermen. United States and Canadian vessels are small and independently owned and operated. Their catches are not processed at sea, but instead are delivered as dressed fish to distant landing ports outside the Bering Sea. Japanese vessels are much larger and owned by a few fishing companies. Soviet vessels are comparable in size to those of Japan, but are owned and operated by the state. Catches are processed at sea aboard Japanese and Soviet vessels. South Korea's pattern of operations is similar to Japan's except that her vessels are generally smaller and older.

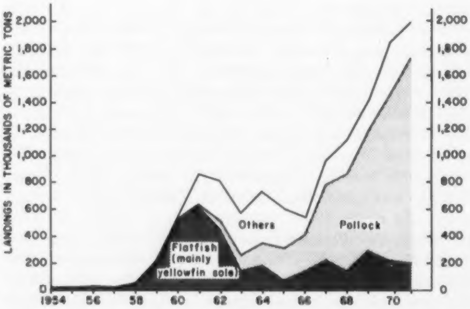

FIG. 2. Estimated landings of flatfish, pollock, and other bottomfish by all nations from the Bering Sea, 1954–71.

Estimates of production by nation from the Bering Sea are given in Table 1 for the years 1954–71, the modern period of the fisheries. Approximate composition of catches by major species or species groups is shown in Fig. 2. In the early period flatfishes (mainly yellowfin sole) accounted for the largest portion of the catch, but recently Alaska pollock has been the primary target. In 1970, Alaska pollock from the North Pacific (about one-half is from the Bering Sea) was tied with Atlantic cod for second place in worldwide landings of a single

TABLE 1. Estimated landings of bottomfish, herring, and shrimp from the Bering Sea by Japan, USSR, United States and Canada, and South Korea, 1954–71, in metric tons.

Year	Japan[a]	USSR[b]	United States and Canada[c]	South Korea[d]	Total
1954	13,000		19		13,019
1955	11,000		20		11,020
1956	27,000		118		27,118
1957	24,000		18		24,018
1958	47,700		987		48,687
1959	159,100	62,000	1886		222,986
1960	444,700	110,000	2562		557,262
1961	622,700	245,000	1799		869,499
1962	498,600	310,000	3321		811,921
1963	312,900	260,000	3691		576,591
1964	413,000	320,000	1011		734,011
1965	395,000	210,000	605		605,605
1966	445,000	100,000	542		545,542
1967	776,000	180,000	1087	5	957,092
1968	968,000	156,000	599	800	1,125,399
1969	1,120,000	282,000	559	4000	1,406,559
1970	1,481,000	350,000	515	5000	1,836,515
1971	1,750,000	235,000	393	5000	1,990,393

[a] Includes land-based dragnet fishery. Landings are from east and west Bering sea.

[b] Author's estimates prior to 1967. Since 1967, figures were obtained from cooperative USA–USSR research agreement and include waters around Aleutian Islands west of Unimak Pass. Does not include waters in western Bering Sea off Asia, believed to be small.

[c] Figures for Pacific halibut, the only USA and Canadian bottomfish fishery in the Bering Sea. Small catches of herring by Alaskan natives not included.

[d] Estimates by US National Fisheries Service personnel in Alaska.

species (both were greatly exceeded by the Peruvian anchoveta).

Status of Resources

The major obstacle in determining the status of resources is lack of comprehensive statistics on catches during development of the fisheries. Fortunately the International North Pacific Fisheries Commission (INPFC) is the repository for an excellent source of data on Japanese fisheries, which account for most of the harvest of bottomfish in the Bering Sea. The following analysis is, therefore, confined to an examination of data on Japanese fisheries. It is largely restricted to the years 1964–70, the period for which the INPFC data are most comprehensive on Japanese fisheries. Catches in years prior to 1964 are considered for those species which can be identified as to subregion within the Bering Sea, based on general knowledge of the historical development of the fisheries.

Although the INPFC data on Japanese fisheries are among the best on bottomfish fisheries anywhere in the world, there are still many problems of interpretation. Factors which have influenced the apparent trends in catch per unit of effort (CPUE) include changes in the practice of discarding some species at sea and improvements in fishing gear, fish detection equipment, and fishing tactics. All of these changes are known to have occurred, but it was not possible to account for them in this preliminary analysis. It should be noted, however, that discard must have been more prevalent in the early period before uses were found for all of the species caught. These factors of increasing retention and reporting of species, together with continued improvements in gear and tactics, would tend to artificially raise values of CPUE in recent years compared to the earlier years and thus might obsucre declines in stock size.

A factor which makes analysis of stock conditions extremely difficult is the pulse nature of Japanese (and Soviet) fisheries. The large mobile fishing fleets generated massive fishing power on localized grounds for a few years, then moved on to other grounds or to other species. It has been demonstrated elsewhere that reducing the size of spawning populations by heavy exploitation can result in lowered recruitment of young fish into a fishery. However, the pulse nature of the Bering Sea fisheries is such that fishing fleets often reduce the size of fishable populations below economically profitable levels, and shift their attention to other stocks before the effects of lowered recruitment to the initial stock become apparent.

The basic statistical area used by Japan in reporting her catches and fishing effort is a block measuring ½° latitude by 1° longitude. A larger reporting unit is a block measuring 2½° latitude by 5° longitude. The latter blocks were used in this analysis and were further combined into 5° longitudinal bands. For each species examined, the data were screened by season and by individual 2½° by 5° blocks to eliminate all values of fishing effort for which no corresponding values of catches were shown. This reduced, but did not eliminate, the error of assigning fishing effort to a secondary rather than to a primary target species.

ALASKA POLLOCK

Alaska pollock is the present target for Japan's mothership and independent trawler fishery. In 1970 Alaska pollock accounted for 84% of the total catches by those fisheries. Some Alaska pollock must be caught inadvertently by Japan's land-based dragnet fishery in the Bering Sea while seeking other species, but as few are reported, those caught must be discarded. It seems unlikely that discarded pollock would survive; hence discards would have to be considered in determining fishing mortality on the resource.

Alaska pollock are not a target for the USSR in the eastern Bering Sea and the extent of their incidental catches is unknown. Incidental catches of pollock may be small, because the Soviet fishery for flatfishes occurs in the winter on the Bering Sea Flats when pollock tend to be in deeper water. However the USSR could at any time make pollock a target and vastly increase fishing pressure on this resource almost overnight.

Alaska pollock are the target for South Korea's fishery in the eastern Bering Sea. Although only 5000 mt are estimated to have been caught by this fishery in 1971, it seems likely that South Korea will increase its effort on this species in the future.

Catches of Alaska pollock and catch per unit of fishing effort (CPUE) values for Japan are shown in Fig. 3 for the years 1964–70. Largest catches have been from grounds between 165°W and 175°W longitude. As a means of examining stock conditions, CPUE was separately determined for Danish seiners, pair trawlers, and stern trawlers. For stern trawlers an additional analysis was made of CPUE for two different size classes of vessels in 1968–70, the only years such data are on file with INPFC.

As shown in Fig. 3, catches and CPUE values for all types of Japanese fishing gear have tended to increase during the period 1964–70, except in the innermost portion of the southeastern Bering Sea (160–165°W longitude). Catches of pollock from 160° to 165°W longitude increased from 28,000 mt in 1964 to 110,000 mt in 1969, then fell off sharply to 10,000 mt in 1970. At least part of the decline in harvest in 1970 was related to the lower values of CPUE attained by pair trawlers and stern trawlers. Only Danish seiners were able to increase their CPUE in 1970 from grounds between 160°W and 165°W longitude.

It is impossible to judge how well the values of CPUE for Japan's fisheries reflect actual changes in abundance of pollock. Some of the increases in CPUE after 1964 must be due to improvements in fishing gear and fishing tactics, and could also be due to discarding at sea of some pollock caught in earlier years when other fishes were the main target species. Such pollock as might have been discarded would not have been reported in the landing statistics and hence the earlier CPUE values would be artificially depressed.

If these factors of improvements in fishing gear, tactics, and possible discard at sea do not account for all of the increase in CPUE, the remainder must have been caused by higher levels of recruitment of young fish. As only a few age groups of pollock support the fishery, the effects of recruitment of an entering year-class are quite pronounced. While recruitment was apparently favorable through 1970, it should be noted that poor recruitment could have a disastrous effect on the fishery. Poor recruitment could cause a diversion of the large Japanese fishing fleet to another target.

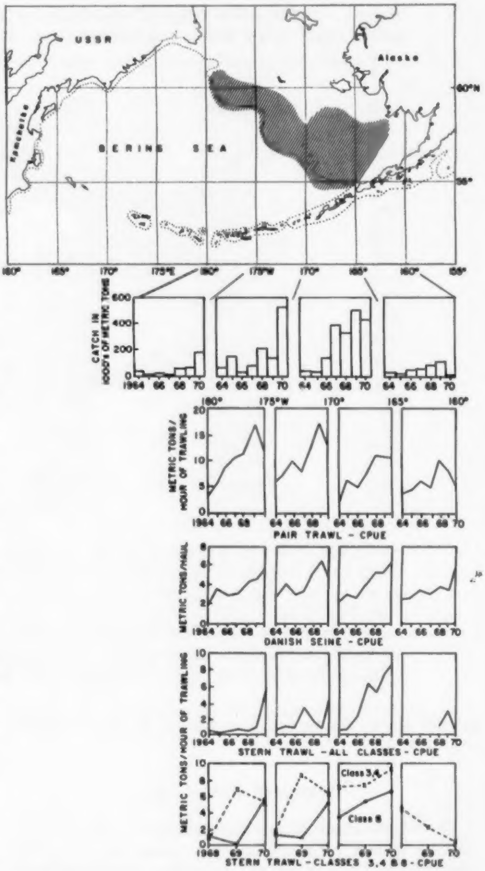

FIG. 3. Total catches of Alaska pollock (*Theragra chalcogrammus*) from the Bering Sea by Japan's mothership, North Pacific trawl, and longline–gillnet fleets, 1964–70 (excluding the land-based dragnet fishery). CPUE values are shown for pair trawlers, Danish seiners, and stern trawlers. (200-m isobath shown by dotted lines.)

PACIFIC COD

Geographical distribution of Japan's catches of Pacific cod is generally similar to that of pollock. Largest catches by Japan of both cod and pollock are taken from grounds between 165°W and 175°W longitude. Some cod must be taken as incidental catches in the fisheries by USSR and South Korea, but quantities are believed to be small compared to Japan's harvest. Similarly, United States and Canadian longliners catch some cod while fishing for halibut. The relatively few cod caught by these longliners are used as bait for halibut.

Total harvest by Japan of Pacific cod from all grounds within the Bering Sea increased from about 19,000 mt in 1964 to 60,000 mt in 1970. Values of CPUE were determined for cod but they are not shown in Fig. 4 because they undoubtedly do not reflect the relative abundance of this secondary target species. Taken at their face value, the CPUE indices for Danish seiners and pair trawlers suggest that the abundance of Pacific cod has increased during the period 1964–70.

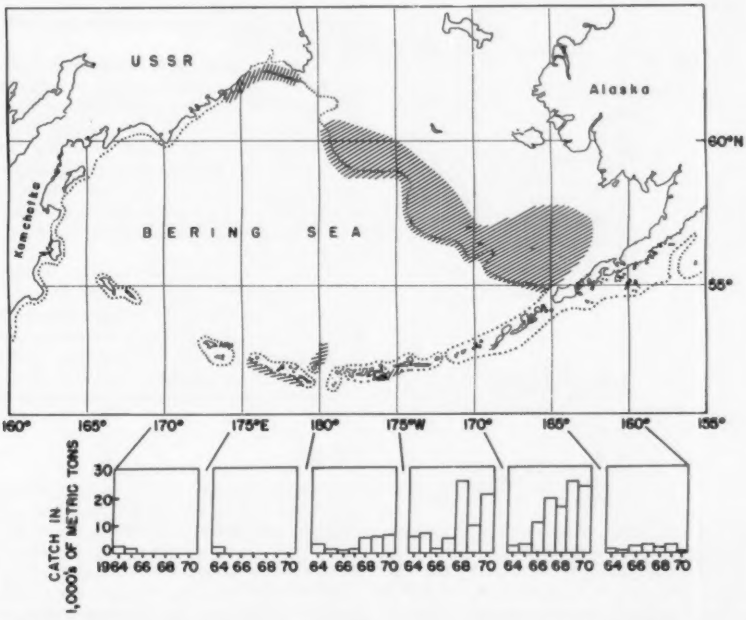

FIG. 4. Total catches of Pacific cod (*Gadus macrocephalus*) from the Bering Sea by Japan's mothership, North Pacific trawl, and longline–gillnet fleets, 1964–70 (excluding the land-based dragnet fishery). (200-m isobath shown by dotted lines.)

YELLOWFIN SOLE

Catches by Japan of yellowfin sole during the period 1958–70 and values of CPUE for the years 1964–70 are shown in Fig. 5. Japan's fishery for yellowfin sole is centered in the southeastern Bering Sea between 160°W and 170°W longitude and mainly occurs in spring and summer. The combined harvest of yellowfin sole by Japan and the USSR peaked in 1961 at about 600,000 mt and has been at a relatively low level since 1963. It is apparent that large catches in the years 1959–62 were more than the stocks could sustain (Kasahara 1972), and there is little likelihood that the resource will be rebuilt to an optimum level as long as it continues to be exposed to uncontrolled fishing.

Values of CPUE shown in Fig. 5 for yellowfin sole are for the period 1964–70, which is after the intense fishery of 1959–62. Data were not available to the author to calculate CPUE values in years prior to 1964.

PACIFIC OCEAN PERCH

Unlike Alaska pollock, Pacific cod, and yellowfin sole, which occur in shallow waters over the inner continental shelf in spring and summer, the Pacific ocean perch is a year-round resident of the deeper waters over the outer shelf and continental slope. Most of Japan's harvest is by independent factory trawlers around the Aleutians and in

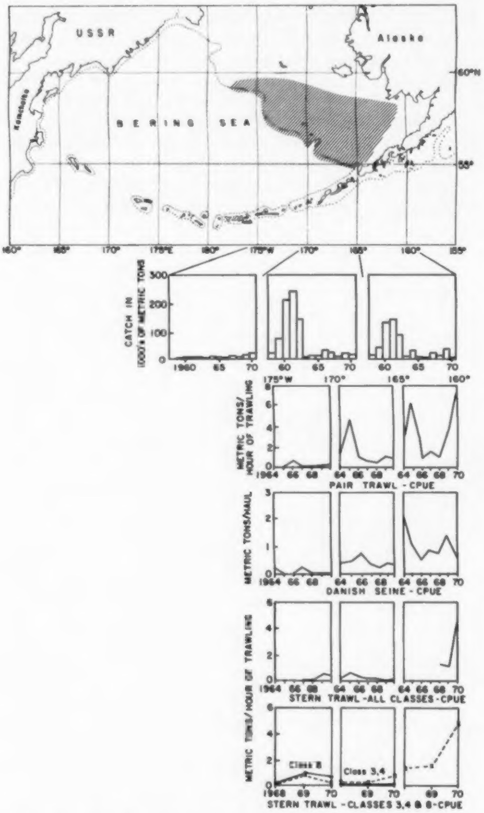

FIG. 5. Total catches of yellowfin sole (*Limanda aspera*) from the Bering Sea by Japan's mothership, North Pacific trawl, and longline–gillnet fleets, 1958–70 (excluding the land-based dragnet fishery). CPUE values are shown for pair trawlers, Danish seiners, and stern trawlers. (200-m isobath shown by dotted lines.)

the southeastern and central Bering Sea. The Soviet fishery is comparable to Japan's, both in areas fished and size of harvests.

Catches of ocean perch by Japan and values of CPUE for stern trawlers are shown in Fig. 6 for the years 1964–70. CPUE values for all classes of stern trawlers combined in the years 1964–70 and for two separate classes of stern trawlers in the period 1968–70 have generally declined within each subregion of the Bering Sea. Declining CPUE, coupled with a reduction in the catches, strongly suggests that the Bering Sea stock of Pacific ocean perch is at a much lower level than in earlier years. Continued exposure to uncontrolled levels of fishing will not be favorable to rebuilding this important resource.

(BLACKCOD (SABLEFISH)

Blackcod (*Anoplopoma fimbria*) has been a target of Soviet trawlers and Japanese longliners and trawlers. Fishing areas are generally similar to those shown for Pacific ocean perch, except that blackcod extend into deeper waters and further southward along Asia. In the early years of Japan's Bering Sea fishery, blackcod were discarded as an unfamiliar species for which there was no demand (Kibesaki 1965). Combined harvests by Japan and the USSR were largest in the early 1960s and have been at a considerably reduced level since the mid-1960s. The harvest by Japan from the Bering Sea sharply increased from 2000 mt in 1960 to 28,000 mt in 1962, fell off to 18,000 mt in 1963, and thereafter has fluctuated between 3000 and 8000 mt. As shown in Fig. 7, the situation of a rapid increase followed by a sharp decrease in production has been repeated within each subregion of the Bering Sea.

Longliners were the dominant element in the early Japanese fishery for blackcod, but since 1963 stern trawlers have taken an increasing and major share of the catch. Presumably the reduced harvest by longliners in the Bering Sea was a major factor in the diversion in 1968 of much of Japan's longline fleet into the Gulf of Alaska. A rapid increase observed in catches of blackcod by the longline fleet in the Gulf of Alaska is ominous in view of the earlier rise and fall of the fishery for that species in the Bering Sea.

CPUE values shown in Fig. 7 for Japanese longliners and stern trawlers cannot be used to evaluate trends in the stock prior to 1964 as detailed data are not available for those years. The generally increasing values of CPUE for longliners since 1964 suggest that some rebuilding of stocks may have occurred. However, this conclusion is not supported by CPUE values observed for stern trawlers.

HERRING

Combined harvest of herring from the Bering Sea by the USSR and Japan was approximately 145,000 mt in 1969 and 143,000 mt in 1970. Most of Japan's harvest in the early period of the fishery was by gillnetters, but stern trawlers have taken most of the catch since 1968. All of the Soviet harvest is by trawlers. The USSR is the major producer of herring from the Bering Sea and as adequate catch statistics are not available to the author, it is difficult to draw conclusions from an analysis of records of the Japanese fishery alone. However, the chronology of Japan's operations for herring in the Bering Sea may in itself shed some light on the status of the resource.

Japan first began fishing for herring off Asia (165–170°E longitude). After a few years of exploiting the Asian stocks, catches fell off sharply and no fishery was reported in 1970. With declining production of the Asian stocks, Japan shifted operations to the eastern Bering Sea where production increased to a peak of 44,000 mt in 1968 and subsequently fell to 15,000 mt by 1970. We may therefore be witnessing a repetition of the rise and fall that occurred earlier off Asia, where the drop in production was accompanied by greatly reduced CPUE (Fig.8). Comparable declines in CPUE are not yet apparent for Japan's herring fishery in the eastern Bering Sea.

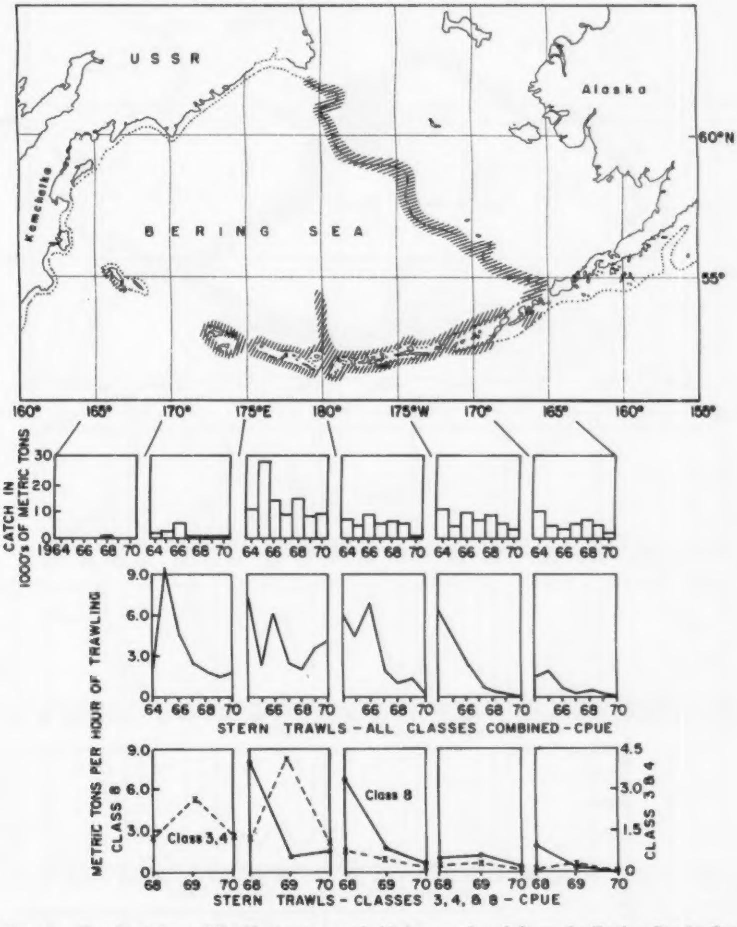

FIG. 6. Total catches of Pacific ocean perch (*Sebastes alutus*) from the Bering Sea by Japan's mothership, North Pacific trawl, and longline–gillnet fleets, 1964–70 (excluding the land-based dragnet fishery). CPUE values are shown for stern trawlers. (200-m isobath shown by dotted lines.)

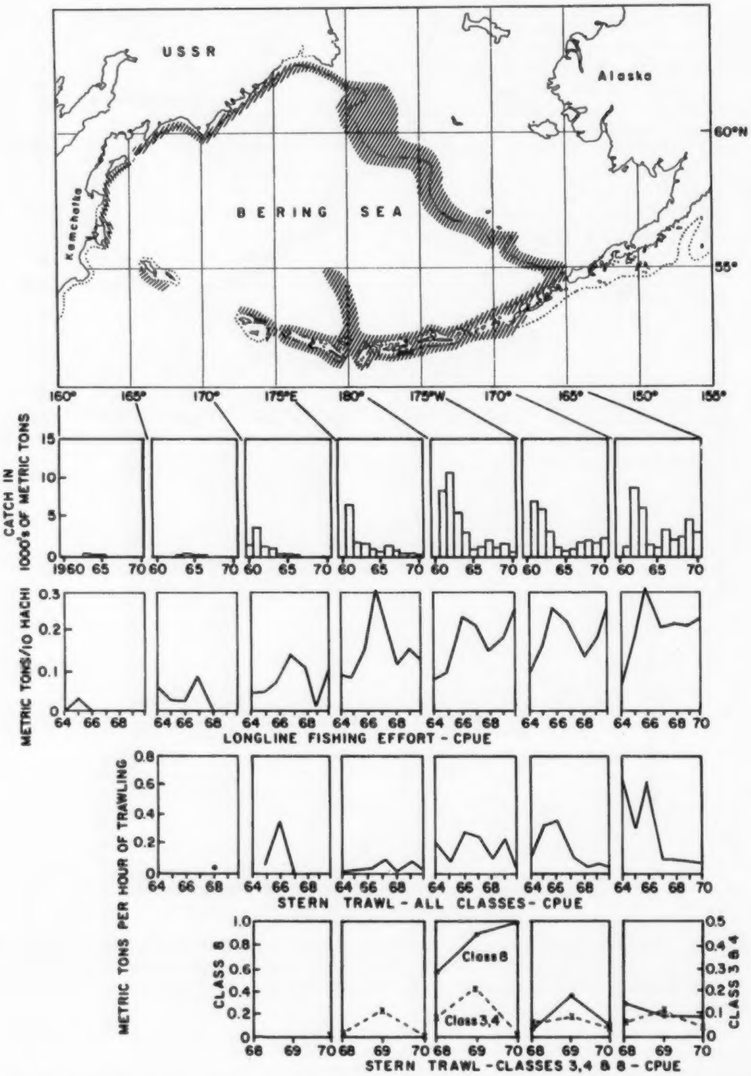

FIG. 7. Total catches of blackcod (*Anoplopoma fimbria*) from the Bering Sea by Japan's mothership, North Pacific trawl, and longline-gillnet fleets, 1960–70 (excluding the land-based dragnet fishery). CPUE values are shown for longliners and stern trawlers. (200-m isobath shown by dotted lines.)

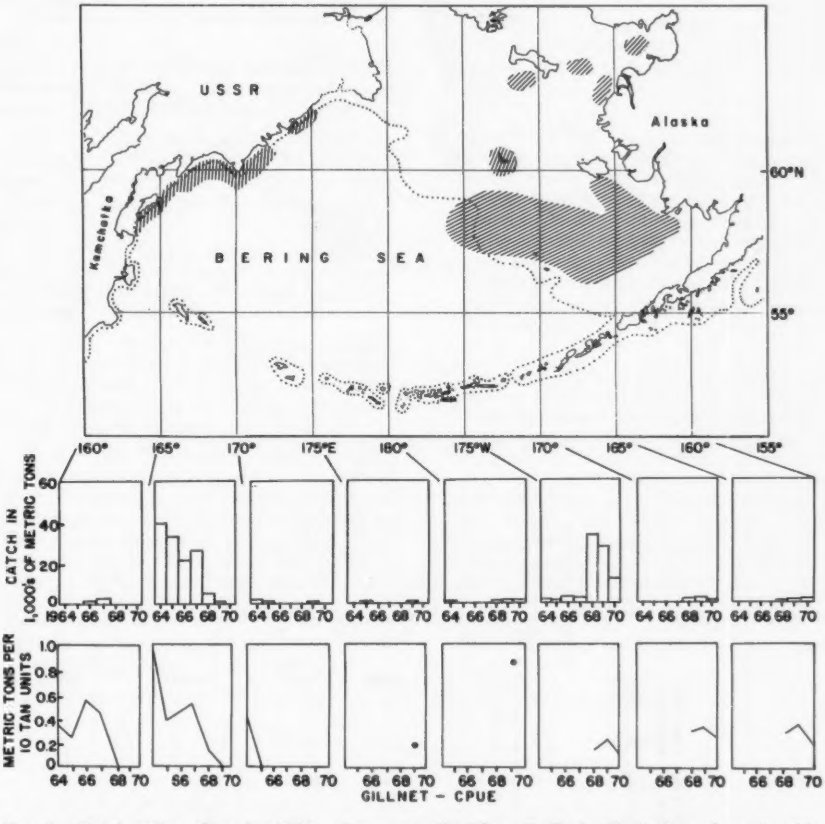
USSR
Alaska
Kamchatka
BERING SEA
60°N
55°
160°
165°
170°
175°E
180°
175°W
170°
165°
160°
155°
CATCH IN 1,000's OF METRIC TONS
0
20
40
60
1964 66 68 70
64 66 68 70
METRIC TONS PER 10 TAN UNITS
0
0.2
0.4
0.6
0.8
1.0
64 66 68 70
66 68 70
GILLNET – CPUE

FIG. 8. Total catches of herring (*Clupea harengus pallasi*) from the Bering Sea by Japan's mothership, North Pacific trawl, and longline–gillnet fleets, 1964–70 (excluding the land-based dragnet fishery). CPUE values are shown for gillnetters. (200-m isobath shown by dotted lines.)

SHRIMPS

The object of Japan's shrimp fishery in the Bering Sea is the small pink shrimp which supports an expanding United States fishery in the Gulf of Alaska. The USSR is reported to have fished for this species northwest of the Pribilof Islands in 1963 and 1964 (Chitwood 1969). Catches of shrimps by Japan and values of CPUE for stern trawlers are shown in Fig. 9.

As with herring, the chronology of Japan's shrimp fishery may be indicative of stock conditions, because the initial fishery in the southeastern Bering Sea was short-lived. It began about 1960, peaked in 1963, and fell to practically nothing by 1969. With declining production Japan shifted operations close to Asia (north of 60°N), where the largest harvest was taken in 1968, the initial year. Catches in this latest shrimp fishery by Japan declined in 1969 and again in 1970.

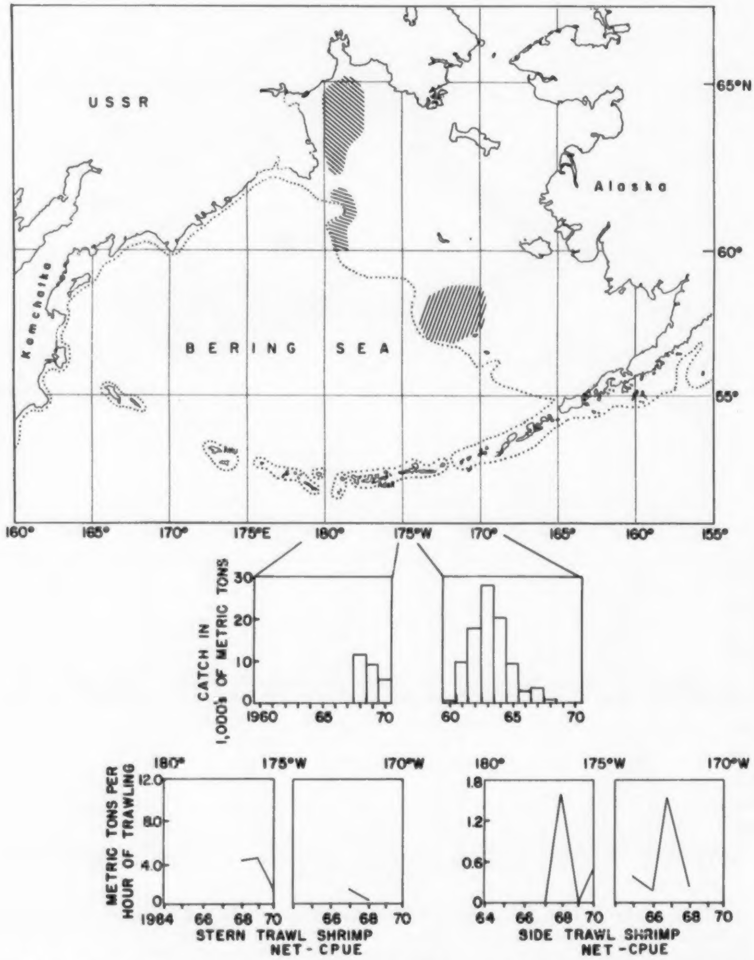
USSR
Alaska
Kamchatka
BERING SEA
65°N
60°
55°
160°
165°
170°
175°E
180°
175°W
170°
165°
160°
155°
CATCH IN 1,000's OF METRIC TONS
30
20
10
0
1960
65
70
60
65
70
METRIC TONS PER HOUR OF TRAWLING
180°
175°W
170°W
12.0
8.0
4.0
0
1964
66
68
70
66
68
70
STERN TRAWL SHRIMP NET - CPUE
180°
175°W
170°W
1.8
1.2
0.6
0
64
66
68
70
66
68
70
SIDE TRAWL SHRIMP NET - CPUE

FIG. 9. Total shrimp (*Pandalus borealis*) catches from the Bering Sea by Japan's mothership, and North Pacific trawl fleets, 1960–70 (excluding the land-based dragnet fishery). CPUE values are shown for stern trawlers and side trawlers. (200-m isobath shown by dotted lines.)

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Salmon Management in the United States[1]

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The salmon fishery of the United States illustrates the major principles and problems of fishery management: regulation of the fishery, maintenance of the environment, and artificial augmentation of the stocks. It also includes controls both in fresh water and on the high seas. The industry has experienced the age-old conflicts between large- and small-scale fisheries, and administrators have had to wrestle with the problem of allocating the catch among various contenders. This problem has been confused with that of conservation. Prohibition of salmon traps, restrictions on size and mode of operation of purse seines, and prohibition of monofilament gillnets are examples of the kinds of compromises made between allocation and conservation.

Dams, pollution, and other modifications of the freshwater environment have endangered salmon stocks. An early response was to raise salmon artificially and release them. For many years this technique was unsuccessful, and when it was evaluated most hatcheries were closed. In recent years the preservation of the genetic identity of the stock and improved diets and schedules of release have resulted in greater success of hatcheries. Spawning channels show promise of additional success. Another practice of value has been development of devices to pass fish over dams, both upstream and down.

Control of fishing to provide adequate spawning has concentrated on manipulation of individual population units, an enormously complicated task since the number of these in United States streams is in the order of 10,000. Of these about 100 major ones are under separate control. Regulations depend on forecasts, since fishing takes place before the salmon reach spawning grounds. Forecasts have improved greatly in recent years, although much remains to be done.

Among problems on which no great progress has been made are: extent and consequences of genetic change produced by selective fishing; causes of cycles, and alterations in these; effects of changing environment, especially subtle ones of temperature, dissolved oxygen, and pollution; control of recruitment, including release of hardy young. Difficult economic problems include: the tendency for regulations to favor inefficient operators; high costs of research and regulation, borne not by users but by public funds.

Administrative achievements include: a high degree of environmental protection; remarkably parallel regulations in the three States principally involved, Alaska, Washington, and Oregon; successful joint regulation of international fisheries in cooperation with Canada and Japan.

Problems which will continue to exist and increase in difficulty include protection of the environment of the salmon, rivalries between many diverse interest groups, and improvement in culture operations. The major step of restricting entry into the commercial salmon fishery is being contemplated in several locations.

L'étude de la pêcherie de saumons des Etats-Unis permet d'illustrer les principes et problèmes fondamentaux liés à l'aménagement des pêches: réglementation de la pêche, maintien de l'environnement et accroissement artificiel des stocks. Entre aussi en ligne de compte le contrôle des eaux douces et de la haute mer. L'industrie connaît depuis longtemps les conflits opposant les grandes et les petites pêcheries, et les administrateurs ont dû s'atteler au problème de la répartition des prises entre les diverses parties en présence. Ce problème a été confundu avec celui de la conservation. L'interdiction des pièges à saumons, la limitation du maillage et les restrictions apportées à l'utilisation des seines coulissantes, ainsi que l'interdiction des filets maillants monofilaments, sont autant d'exemples de solutions de compromis entre répartition des contingents et conservation des ressources.

La construction de barrages, la pollution et d'autres modifications du milieu dulcaquicole menacent les stocks de saumons. Une solution ancienne a consisté à entreprendre l'élevage artificiel de ces poissons et à les lâcher dans les cours d'eau. Cette technique a été infructueuse pendant de nombreuses années et, quand on a l'évaluer, la plupart des écloseries avaient fermé. Ces dernières années, la préservation de l'identité génétique du stock et l'amélioration du nourrissage et des plans de lâchers ont accru l'efficacité des écloseries. La construction de chenaux de frai semble riche de promesses. Une autre technique intéressante est représentée par l'installation de dispositifs permettant aux poissons de franchir les barrages, tant vers l'aval que l'amont.

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

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Les opérations de contrôle de la pêche visant à assurer une reproduction adéquate ont essentiellement porté sur la manipulation de populations individuelles, tâche d'une complexité colossale puisque l'on compte quelque 10,000 populations de poissons dans les cours d'eaux des Etats-Unis. Une centaine des principales populations font l'objet d'un contrôle distinct. Les réglementations reposent sur des prévisions, car la pêche intervient avant que le saumon n'atteigne les frayères. Les prévisions se sont grandement améliorées ces dernières années, encore que beaucoup reste encore à faire dans ce domaine.

Parmi les problèmes dont la solution n'a pas avancé, on peut citer les suivants: ampleur et conséquences des modifications génétiques provoquées par la pêche sélective; causes des cycles, et modification de ces derniers; effets de la transformation du milieu, en particulier répercussions subtiles associées à la température, à la teneur en oxygène dissous et à la pollution; contrôle du recrutement, notamment lâchers de jeunes ayant une rusticité élevée. Il existe aussi des problèmes économiques ardus: tendance de la réglementation à favoriser les opérateurs inefficaces; coût élevé de la recherche et de la réglementation, couvert non par les usagers mais au moyen des deniers publics.

Sur le plan administratif, plusieurs réalisations sont à signaler: degré élevé de protection écologique; promulgation de règlements d'un parallélisme remarquable dans les trois principaux Etats intéressés, Alaska, Washington et Orégon; application efficace d'une réglementation commune des pêcheries internationales en coopération avec le Canada et le Japon.

D'autres problèmes continueront à se poser, dont la solution augmentera en difficulté: protection écologique du saumon, rivalité de groupes d'intérêts divers et nombreux, amélioration de la salmoniculture. En plusieurs endroits, on envisage comme principale mesure de restreindre l'entrée dans la pêcherie commerciale de saumon.

La pesquería de salmón de los Estados Unidos permite ilustrar los principios y problemas más importantes implicados en la administración de una pesquería: reglamentación de la pesca, conservación del medio ambiente, e incremento artificial de la población. Incluye además una serie de controles tanto en agua dulce como en alta mar. La industria ha experimentado los antiquísimos conflictos entre pesquerías a grande y pequeña escala y los encargodos de la administración de la pesquería han tenido que abordar el problema de distribuir las capturas entre los diversos sectores que aducían sus derechos. Este problema se ha confundido con el de la conservación del empleo de trampas salmoneras, la limitación de las dimensiones y del modo de empleo de las redes de cerco, y la prohibición del uso de redes de enmalle de monofilamento son ejemplos de los tipos de compromisos a que se ha llegado entre la distribución de los recursos y la conservación de los mismos.

La construcción de presas, la contaminación y otras modificaciones de los ambientes de agua dulce han puesto en peligro las poblaciones de salmones. La respuesta inicial a este problema fue criar salmones artificialmente y soltarlos. Durante muchos años esta técnica no tuvo éxito y cuando se cayó en la cuenta de ello la mayoría de las piscifactorías habian ya cerrado. En los últimos años, la conservación de la identidad genética de la población y la mejora de las dietas y los programas de suelta ha permitido un mayor éxito en las piscifactorías. La construcción de canales de desove promete nuevos éxitos. También ha sido importante la introducción de sistemas que permiten a los peces pasar por encima de las presas, tanto contra la corriente como a favor de ella.

El control de la pesca para permitir un desove adecuado se ha concentrado en la regulación de las poblaciones una por una, tarea enormemente complicada ya que el número de poblaciones en los cursos de agua de los Estados Unidos es del orden de 10,000. De unas 100 de éstas, más importantes, se mantiene control por separado. Estas reglamentaciones se basan en previsiones, ya que la pesca se realiza antes de que el salmón llegue a los frezaderos. Los pronósticos han mejorado notablemente en los últimos años, aunque es mucho lo que queda aún por hacer.

Entre los problemas sobre los que no se han logrado grandes progresos figuran: la amplitud y las consecuencias de los cambios genéticos debidos a la pesca selectiva; las causas de los ciclos y las alteraciones de los mismos; los efectos de las variaciones del medio ambiente, especialmente las variaciones ligeras de temperatura, oxígeno disuelto y contaminación; el control del reclutamiento, incluida la suelta de formas juveniles robustas. Entre los problemas económicos de difícil solución figuran: la tendencia de las reglamentaciones a favorecer a los pescadores menos eficientes; los elevados costos de investigación y reglamentación, que no sólo sostienen los usuarios sino que es preciso costear con fondo públicos.

Entre los logros administrativos figuran: una notable protección del medio ambiente; la introducción de reglamentaciones paralelas en los tres Estados principalmente afectados, Alaska, Wáshington y Oregón; el éxito en la regulación conjunta de pesquerías internacionales en colaboración con Canadá y Japón.

Entre los problemas que perdurarán e incluso aumentarán en dificultad puede citarse la protección del medio ambiente del salmón, las rivalidades de muchos grupos diversos de intereses, y la mejora de las operaciones de cultivo. En varios lugares se está examinando la posibilidad de tomar la importante medida de limitar el acceso a la pesquería comercial de salmón.

THE salmon fishery management in the United States provides a marvelous example of the intricate relations between fishing and governments. It demonstrates well all of the principles and problems of fishery management, including regulation of fishing, maintenance of the environment, and artificial augmentation of stocks. It also involves the problems of managing both high-seas fisheries and freshwater fisheries.

Any brief broad coverage of this large topic follows the work of many authors. I will summarize and emphasize largely on the basis of judgments developed during 15 years of directing research on Alaskan salmon. During most of this period I was a faculty member of the College of Fisheries at the University of Washington, and my views expressed here are independent of any United States Government policies. I shall make only a scanty attempt at documentation by listing some comprehensive references, but I acknowledge a substantial debt to Larkin (1970) who presented an historical summary in broad perspective.

Background of Technical Data

The five species of eastern Pacific salmon are anadromous fish that breed in fresh water and fatten in the sea. They occur along the coast of western North America from central California to the Arctic Ocean. The eggs are laid in loose gravel through which water percolates and where the eggs and larvae are sheltered for several months, usually during the first winter of life. The larvae emerge from the gravel and begin to feed in shallow sheltered waters of streams and lakes in the case of sockeye, chinook, and coho, and along the shores of estuaries in the case of chum and pink. At lengths of from 7 to 15 cm they migrate from sheltered waters to feeding grounds in larger bays or the open sea, where they remain for from 1 to 5 years depending on species and stock, before they reach adulthood and return to spawn.

Almost all of the United States fishing has been conducted on the adult salmon as they return to their home streams. They are easily caught at this time of life along the sea coasts, or in the estuaries and streams. They are also at the peak of their fatness because it is the time at which they usually stop feeding and begin to draw on their stored energy during their migration up the rivers and during the spawning process, after which they die. An exception to this practice of taking the fish as they are maturing occurs with some chinook and coho salmon which live in the larger estuaries and along the coasts throughout their saltwater lives, where they are available to hook and small-scale net gear. Another exception occurs with foreign fishing which takes North American salmon on the high seas of the North Pacific.

An outstanding feature of the life of the salmon and one which enormously complicates the regulatory process is the homing instinct. The salmon have homes in fresh water where they breed that may be thousands of kilometers from their homes in the sea where they feed. They migrate between their freshwater and ocean homes with remarkable accuracy on a close schedule and with little wandering. This complex life is a result of evolution in which a genetic strain of fish locates a spawning area where the eggs will be protected, and from which the larvae will emerge at the right time to find food and shelter and begin a migration to feeding grounds which will sustain them until they return. Each animal performs this migration only once, and the ability to maintain such timing and routing are inherited characteristics.

The salmon fisheries provided a food resource for the native peoples of western North America for thousands of years before the entry of the Caucasians during the nineteenth century. Apparently they were the major source of protein food for several hundred thousand people in coastal tribes between California and northern Alaska. The salmon were caught during their ascent of the rivers and preserved to provide food during much of the year. The gear consisted of a variety of ingenious hooks, spears, dipnets, and traps or barricades. With the appearance of the European explorers, salt salmon and later canned salmon began to be traded. The first canned salmon pack was prepared in 1866 in Sacramento, California, and its success encouraged others to start canneries farther north soon afterward. Many were erected during the 1870s to use the massive runs of the Columbia River, and the success of these encouraged the development of other canneries in Washington and Alaska during the late 1870s and 1880s. By 1900 all of the major fishing areas of Alaska had canneries and salteries.

The fisheries have gone through the now familiar fishery cycle of boom and bust, of fortunes made and lost, of production climbing to a high plateau (where it was sustained for about 20 years) and then collapsing to about one-half the level once sustained (Table 1). Not only has the salmon fishery as a whole gone through this cycle, but most of the fisheries on separate stocks have gone through a similar cycle at times for varying combinations of reasons.

TABLE 1. United States production of Pacific salmon:[a] Average annual totals, in thousands of metric tons.

Period	Sockeye	Chinook	Coho	Pink	Chum	Total
1892, 1895, 1899 (avg)	–	–	–	–	–	63.2[a]
1900–09	63.5	11.7	8.6	18.6	7.3	109.7
1910–19	74.3	16.1	15.5	64.4	33.5	203.8
1920–29[b]	59.5	25.7	19.5	88.9	34.5	228.1
1930–39	68.4	21.7	17.6	113.4	31.3	252.4
1940–49	47.9	21.0	17.5	90.2	31.1	207.7
1950–59	35.6	16.4	14.8	44.6	28.4	139.8
1960–69	36.7	12.1	13.2	53.5	21.4	136.9

[a] Data for 1903–19 from the 1934 Pacific Fisherman Annual. Figures for case packs were converted to fish weight by conversion factors of 32.7 kg per case for sockeye, chinook, coho, and chum salmon, and 33.6 kg per case of pink salmon. Data do not include fish processed by any method other than canning. "Other than canned" salmon products for all species ranged from 2.2 to 7.4 thousand metric tons annually, averaging 4.5 thousand metric tons for the years 1906–19.

[b] Average based on 1922–29 data. Data for 1922–49 from records of the U.S. National Marine Fisheries Service, for 1950–69 from FAO Yearbooks of Fishery Statistics.

The salmon fisheries have been an exceptionally fertile situation for development of the age-old conflict between large-scale and small-scale fisheries. The earliest fisheries were prosecuted easily by individuals with hook, spear or dipnet, and even simple traps and barricades in streams required few people for their construction. The fisheries still provide a unique way of life for individuals or husband and wife teams who fish from small boats with hook and line ("troll") gear or gillnets. In addition, a large number of the hook and line fishermen fish merely for fun with no expectation of profit. The individuals so involved have protested bitterly over the years as other fishermen have set large traps or fished with huge seines.

The problems of allocating the catch among those with different equipment have probably always been confused with the problems of conservation. It was obvious to the earliest fishermen that some salmon must be left to spawn. Many of them are reported to have controlled their barricades or traps in order to allow this. Then the individual fisherman could argue that his small efforts were not significant in preventing the salmon from reaching their spawning areas; it was the big efficient fisherman who should be controlled. Similar arguments have waxed furiously since Caucasians have been fishing. Included are claims from the recreational fisherman who argue that their interest is more important than that of the person who merely catches the fish to sell for food.

Gear conflicts still abound, as they have for most of the present century. The individual and small-boat fisherman, being more numerous, have forced a severe restriction or even abolition of large efficient gears. The large salmon traps are now prohibited by law except in the case of a few which are operated by native Alaskans under special government permit. The large purse seine gear is sharply restricted in size and mode of operation. Also restricted are size of vessel, labor saving gear for handling the net on board the vessel, and aerial scouting methods. Even the gillnets are restricted in length and the efficient monofilament nylon is prohibited.

The attempts at regulating fishing have long been a mixture of compromise between problems of conservation and allocation. At about the beginning of the twentieth century laws were passed, or at least advocated, to provide spring and fall closed seasons, Sunday closed seasons, closed areas in certain spawning tributaries, prohibition of the use of explosives or poisons, protection of immature salmon, prohibition of spears or unusually efficient hooks, prohibition of poaching, limitation on size, length and mesh of poundnets and gillnets.

But it was obvious to everyone early in this century that fishing was not the only hazard to salmon because in the States of California, Oregon, and Washington many streams were dammed to provide power or water for irrigation. The smaller tributaries were dammed in the latter part of the nineteenth century and the first three decades of the twentieth century. By then it became possible to dam the largest rivers, the Columbia and Sacramento. Many of these dams destroyed stocks of salmon long before attempts were made to provide fish passage facilities, but during the 1920s and 1930s methods of constructing fish passage facilities around moderate sized dams were discovered and generally required.

For the first 60 years or more of the modern salmon fishery, attempts to restrict catch or to provide expensive passage facilities over dams were met with the suggestion that salmon be raised artificially. This was an outgrowth of the rediscovery of the techniques of rearing trout and salmon in hatcheries in Europe during the middle part of the nineteenth century and the extravagant claims made by fish culturists. Trout and salmon hatcheries were introduced in the United States in the 1860s and 1870s and found many advocates. The simple statistics of releasing millions of young from them was enough to compensate politically for the capture of thousands of salmon or the blockage of dozens of small streams although their value soon began to be doubted.

The faith in the efficacy of fish hatcheries was shaken by a variety of events. First a number of hatcheries were constructed in Alaska during the early years of the twentieth century in response to a Federal law that granted tax reductions to companies that would operate such hatcheries. Some of these failed because they eliminated the runs of fish from which they were taking their brood stock. Later during the 1920s and 1930s came a rigorous examination of the efficacy of the salmon hatcheries in British Columbia which resulted in a decision to close all salmon hatcheries in that province, and later in Alaska. Hatcheries continued to operate in the States of Washington and Oregon but the doubts persisted, and even in the 1950s the United States Federal Government contracted for a inquiry into why one of their hatcheries seemed to be successful when most of the others were not. (This skepticism was followed by a vigorous investigation into the causes of the shortcomings of the salmon hatcheries and their correction as will be noted later.)

With this background I shall now try to describe the status of the management of salmon by a brief account of what I regard as major achievements and major problems.

Scientific and Technical Achievements

THE LIFE OF THE SALMON

The major features have been well known for such a long time that we tend to overlook the scientific efforts in their discovery. The spawning process, development of young, the environmental requirements of each stage and their habits and behavior have been studied by scores of biologists as they have tried to explain the things that have happened to the salmon, or to create better conditions for them. Their extraordinary ability to locate their freshwater homes was described decades ago but the use of their high-seas homes has been detailed only within the last decade. The principles and variations in these matters fill a large portion of the scientific salmon literature.

SALMON CULTURE

Following development of salmon hatcheries, and a long period of faith in their efficacy, came a substantial scientific input and a correction of the principal shortcomings. First came an intensive study of the diseases of salmon in captivity and of the basic nutritional requirements of the young. Then came a hard pragmatic evaluation of the management of the hatcheries. It appears that several factors had been neglected. Among these were preservation of the genetic identity of the stock and its ability to return to a single location, development of a superior diet which eliminated the transfer of disease from adult to young (raw salmon carcasses had been used in the diet), and schedules which released the salmon in the river or ocean at times when they could find food and not be decimated by predators.

The expense of hatcheries and the relatively successful natural propagation under ideal circumstances has led also to a variety of attempts to control the environment during the more hazardous stages in the life of the young. Artificial spawning channels with ideal water and gravel conditions in which the fish can be allowed to spawn naturally have been developed and used successfully in a number of areas. In addition, artificial gravel incubation systems are being developed.

TRANSPORT SYSTEMS

In order to permit salmon to use spawning areas above dams or natural obstructions, and to prevent their entering hazards such as power intakes or irrigation intakes, a variety of structures have been developed. On low dams, stair-step arrangements of pools, called fishways, have been built and located in such a way that the migrating salmon can find and ascend them. The young salmon can come back downstream over low dams (less than about 20 m) with little hazard but as the dams get higher and falling water more violent they are killed, and a number of systems have been introduced to guide them down relatively safe passageways. Much effort has gone into the development of screens on diversion canals to keep the young salmon in their normal downstream channels.

REGULATION OF THE FISHING

The regulatory systems pose a problem of extraordinary complexity because of the multitude of population (genetic) units which have individual migration routes and schedules. Each species in each river is at least one unit, and in many larger rivers more than one unit of a single species enters to spawn in different locations at different times. No accurate count of population units is available but it is of the order of 10,000.

These population units are characteristically combined into management units called stocks. A stock is comprised of the population units in one place and during a period of time which for practical reasons must be controlled as a single unit. The result has been the identification and separate control of the fishing on more than a hundred major stocks between California and northern Alaska.

The control over fishing on each stock is exercised to provide an adequate spawning escapement. The adequacy is judged either on the basis of the degree of crowding on the spawning areas or of the stock-recruitment relation. The latter is typically a dome-shaped curve, in which the greatest surplus of catch over spawners due to escapement is usually between ⅓ and ⅛ of the maximum size of returning runs (Fig. 1).

Such control is difficult because the runs come through the inshore fishery quickly and the catch must be taken before escapement can be accurately counted. The regulatory decisions must therefore be based on forecasts, developed from a variety of bases. The control system is also assisted by determinations of age and sex composition of returning runs of the species with a longer life history. Although much remains to be done, there has been a great improvement in the precision of the regulatory system, especially since 1950.

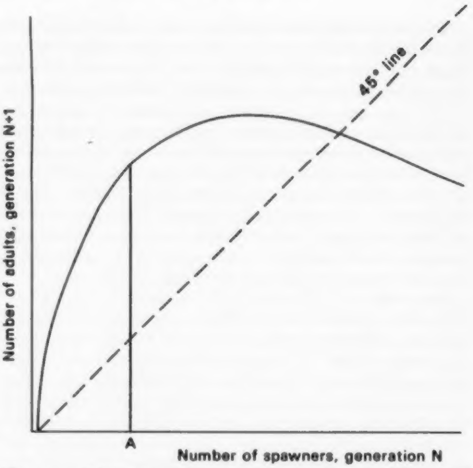

Fig. 1. Diagram of escapement return relation for salmon. Point A indicates the number of spawners which on the average will produce the greatest surplus of catch.

Scientific Problems

The significant scientific and technical successes in salmon fishery management have been accompanied by identification of a number of substantial problems on which no great progress has been made. The major ones are:

EXTENT AND CONSEQUENCES OF GENETIC CHANGE

A large part of the fishery has been selective of certain runs or certain sizes or certain ages; hence we have had a different fishing effort on the genetic components. For example, the early pink salmon runs in southeastern Alaska have been fished much more heavily than the later runs; the large sockeye in Bristol Bay have been fished much more heavily than the small because of the selectivity of gillnets. Similar unevenness in the fishing effort can be noted in most areas. The consequences are not understood but they must develop slowly and may be a factor in the smaller size of some modern runs.

CAUSES OF CYCLES

Many runs of salmon conform to a constant cycle of abundance, whereby large runs occur at fixed intervals of years. Sometimes these cycles have been altered by fishing or natural catastrophes or by artificial transfer of fish, but in other cases a change has been extraordinarily intractable. Part of the phenomenon has been explained by related cycles in predators, which lag behind the cycles in salmon, but this does not appear to be a complete explanation.

EFFECTS OF CHANGING ENVIRONMENT

The effects of gross changes are well known, but the effects of the subtle changes in temperature, flow, dissolved oxygen, and minor pollution in the rivers are not well understood. Neither are techniques which might be taken to augment the salmon populations, such as control of predators or competitors.

CONTROL OF RECRUITMENT

One important consequence of the decline of salmon stocks, regardless of cause, is a reduced capacity to seed the ocean with juvenile fish. In some cases we can exercise control through restriction of the harvest, to allow the proper number of spawners in the escapement, but many economic and environmental forces oppose the success of regulation of harvest for "optimum escapement". There may also be emerging opportunities to use technology to increase egg-to-fry survival from about 10% in the case of natural spawning to about 50% in the case of spawning channels and about 90% in the case of hatcheries. There are still many problems yet to be solved to ensure that the artificially propagated fry are nearly equivalent to wild fry with regard to their fitness for growth and survival, but the possibility of achieving up to a ninefold increase in efficiency of reproduction of salmon affords a highly significant economic opportunity for the future development of salmon resources.

Economic Problems

The salmon fisheries have long been one of the most valuable of United States fisheries. Consequently, it seems absurd that they are beset with severe economic problems. These are of two kinds:

The tendency to favor by regulation the small, less efficient fisherman prevails throughout the salmon fisheries. Most of the catch regulation in the interest of conservation requires a reduction in fishing effort which is achieved by reducing efficiency rather than by reducing the number of fishermen. In some areas during years of small runs, fishermen are idle more than 90% of the time. This leads to a chronically low level of income among the average salmon fisherman and to higher prices being paid for their catches.

The cost of research and the complicated task of regulation is a severe restraint on efficiency of the regulation. Characteristically, the cost of research and regulation is sustained in large part by general government funds rather than by special taxes on the fisheries. The costs of special facilities to protect and transport salmon, or to provide compensation through hatcheries, is borne in part by the users of water and in part by general government funds.

Administrative Achievements

ENVIRONMENTAL PROTECTION AND COMPENSATION

During the rapid modification of the freshwater environment of the salmon under the stress of agricultural, urban or industrial change, a large measure of protection or compensation has been achieved. The best indicator of this is the substantial salmon runs that remain in the Columbia River despite the loss of large spawning areas and the intensive use of this river for many purposes. This has cost hundreds of millions of dollars, but sustaining the salmon remains a major goal in the use of this river as in the use of other rivers and streams.

DOMESTIC REGULATION

The regulation of the fishing is entirely a function of the separate States and not of the Federal Government of the United States, but there are remarkable parallels in the regulations of the principal States involved — Oregon, Washington, and Alaska. In all of them there has been a steady evolution of regulations based on increased scientific information about the runs and the consequences of regulatory action. The principal regulation in the interest of conservation, the day-to-day division of the runs between catch and escapement, has been largely delegated by the legislators to the state departments of fisheries, which base decisions on scientific evidence. Washington and Oregon, which share a common fishery in the Columbia River, have regulations which are almost wholly compatible.

INTERNATIONAL REGULATION

The principles that emerged in domestic regulation along the Pacific Coast in both Canada and the United States have carried over into an especially precise joint regulation of the fisheries of the Fraser River salmon, which are conducted along the United States–Canadian border. A Convention was adopted in 1937 which provided for scientific research, regulations based on that research, and equal division of the catch of sockeye (and later pink salmon) between the two countries.

Later, when high-seas fishing for salmon became imminent in the 1950s, the United States, Canada, and Japan negotiated a treaty which provides for substantial, though not complete, control of high-seas fishing on North American stocks. This treaty was augmented by prohibition in Canada and the United States of net fishing (before it became extensive) for salmon anywhere outside the outer coasts. By this action they retained a large measure of the control of individual salmon runs which is the key to their regulation for conservation purposes.

Administrative Problems

These substantial administrative achievements are merely stages in the solution of continuing problems constantly changing as society changes.

Environmental problems continue to become more acute as the use of water and land for other purposes becomes more intense. The administrators must continue to devise effective compromises between the competing users if such are possible, or stand fast where they are not.

Problems of regulation can be expected to increase for years to come. The rivalries between individual fishermen and large-scale fishermen, between recreational and commercial fishermen, between fishermen of one nation and those of another can only be expected to accelerate.

Changes in allocation among fishermen that follow every move to regulate for conservation will continue to plague the administrators. The major step of restricting entry into the commercial salmon fishery is being contemplated in several places and a variety of legislative skirmishes have occurred. No effective action to limit fishermen has yet been taken in the United States salmon fishery, however, but all concerned are looking intensively at the experience of the Canadian government which has moved to restrict the number of salmon fishermen in British Columbia.

Another regulatory problem is emerging as public salmon culture becomes more efficient. Cultivated stocks can be harvested at much higher rates than wild stocks, without reducing recruitment, and regulation of mixed stocks frequently allows surplus spawners at the hatcheries.

Finally, *private salmon culture* is emerging as an opportunity and a challenge. Improved salmon cultural methods are attracting private investors into two kinds of enterprises. One is pen rearing of salmon in salt water, and the other is the ownership of artificial salmon runs that do not mix appreciably with wild stocks in the fisheries. Both of these appear to be desirable business opportunities, but their public control raises some new social and administrative problems.

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Management of the Pacific Halibut Fishery[1]

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The International Pacific Halibut Commission (IPHC) has managed the Canadian and United States halibut fishery since 1923. During the early years of the Commission the abundance of the halibut stocks was declining and there were major changes in fishing techniques. After 1930 the Commission instituted more regulatory control, and catches gradually improved, reaching a maximum in the early 1960s. Some scientists attribute IPHC's success to its organizational structure; others credit the simplicity of the fishery; still others contend that success was possible because the two nations have similar cultures. A more important factor has been the control of the fishery, i.e. the authority to introduce conservation measures that are supported by adequate enforcement.

Since 1960 IPHC has lost control of certain elements in the fishery, and the abundance of halibut has declined markedly. The total catch by the North American longline fleet in 1962 was approximately 45,000 metric tons, while in 1972 it was 25,000 metric tons (round weight). Maximum catch per unit effort (CPUE) was reached before the expansion of domestic (Canada and United States) and foreign trawling. In the late 1950s IPHC had increased the removals to test the estimated maximum sustained yield (MSY) of the stock and expected a decline in CPUE when fishing intensity was increased; however, the rate of decrease was greater and lasted longer than anticipated. Changes in recruitment may have contributed to this decline. By 1965, the incidental catch of halibut by foreign and domestic trawl fisheries had increased substantially, and this accelerated the decrease in abundance. Reductions of the catch limits of the longline fleet failed to arrest the decline. In addition, longline fishermen had improved the effectiveness of their gear by increasing the spacing between hooks; as a result IPHC's measure of CPUE since 1960 was overestimated. The effects of this gear change are far reaching and basic parameters of the halibut populations must be reassessed. Though the fishery has changed measurably, and IPHC has lost some control through the incidental catch by trawlers, a viable fishery has been maintained through the sacrifice of yield by the North American longline fleet. Productivity of this fishery is in jeopardy because losses to trawl fleets are not controlled, and continue to increase.

La Commission internationale du flétan du Pacifique s'occupe depuis 1923 de l'aménagement de la pêcherie canadienne et américaine de flétan. Dans les premières années qui suivirent sa création, l'abondance des stocks de flétans a diminué et les techniques de pêche ont subi d'importantes modifications. Après 1930, la Commission a renforcé les mesures de contrôle, et les captures se sont améliorées graduellement pour atteindre leur maximum au début des années soixante. Certains spécialistes attribuent le succès de la Commission à sa structure organisationnelle, d'autres à la simplicité de la pêcherie et d'autres encore au fait que les deux nations en cause sont de même culture. Un facteur plus important est représenté par l'application de mesures de contrôle dans la pêcherie, c'est-à-dire la possibilité de mettre en oeuvre des mesures de conservation associées à des activités adéquates de surveillance.

Depuis 1960, certains éléments de la pêcherie échappent au contrôle de la Commission et l'abondance du flétan a fortement décliné. Les captures totales faites en 1962 par les palangriers nord-américains ont atteint environ 45,000 tonnes; elles n'étaient plus que de 25,000 tonnes (poisson entier) en 1972. Le taux maximal de captures par unité d'effort e été atteint avant l'expansion des opérations nationales (Canada et Etats-Unis) et étrangères de chalutage. Au cours des années 1956–60 la Commission a augmenté les prévèvements pour tester le rendement maximal équilibré estimatif du stock et a prévu une diminution des captures par unité d'effort consécutive à l'accroissement de l'intensité du pêche; toute-fois, la diminution a été plus importante et plus longue que prévu. Il se peut que des modifications du recrutement aient concouru à ce déclin. En 1965, les prises occasionnelles de flétans par les chalutiers nationaux et étrangers ont augmenté sensiblement, ce qui a accéléré la diminution de l'abondance. L'abaissement des limites de capture de la flottille de palangriers n'a pas permis d'interrompre ce fléchissement. En outre, les palangriers ont amélioré l'efficacité de leurs engins en augmentant l'intervalle entre les hameçons; de ce fait, les mesures des captures

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

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par unité d'effort réalisées par la Commission depuis 1960 sont des surestimations. Les effets des modifications apportées aux engins sont profonds et il faut réévaluer les paramètres fondamentaux des populations de flétans. Bien que la pêcherie ait subi une évolution notable et que certains de ses éléments échappent au contrôle de la Commission du fait des prises occasionnelles par les chalutiers, une pêcherie viable a pu être maintenue moyennant le sacrifice du rendement par la flottille nord-américaine de palangriers. La productivité de cette pêcherie est menacée, parce que les "pertes" imputables aux chalutiers se poursuivents sans contrôle.

La Comisión Internacional de Pesquerías del Pacífico se encarga de regular la pesquería de hipogloso del Canadá y los Estados Unidos desde 1923. Durante los primeros años de existencia de la Comisión, la abundancia de las poblaciones de hipogloso iba en disminución y se produjeron cambios importantes en las técnicas de pesca. A partir de 1930 la Comisión estableció más controles y las capturas mejoraron, gradualmente, hasta alcanzar un máximo al principio de los años sesenta. Algunos científicos atribuyen el éxito de la Comisión a su estructura orgánica, otros a la sencillez de la pesquería, y otros aún al hecho de que los dos países que participan en ella tienen culturas análogas. Un factor más importante ha sido el control de la pesquería, es decir, la autoridad para introducir medidas de conservación por cuya aplicación se vela adecuadamente.

Desde 1960 la Comisión ha perdido el control de algunos elementos de la pesquería y la abundancia del hipogloso ha disminuido notablemente. La captura total de la flota de palangreros de América del Norte fue en 1962 de unas 45,000 toneladas, mientras en 1972 fue de 25,000 toneladas (peso en fresco). La captura por unidad de esfuerzo llegó al máximo antes de la expansión de la pesca al arrastre por parte de los países participantes (Canadá y Estados Unidos) y de otros países. Al fin de los años cincuenta, la Comisión había incrementado la explotación para comprobar en la práctica el rendimiento máximo sostenible estimado de la población y esperaba que al aumentar la intensidad de pesca se produjera una disminución de la captura por unidad de esfuerzo, pero el índice de disminución fue mayor y duró más de lo que se había previsto. Tal vez los cambios en el reclutamiento hayan contribuido a esta disminución. En 1965, las capturas accidentales de hipogloso en las pesquerías de arrastre de los dos países que participan en la Comisión y de los demás países habían aumentado sustancialemente, contribuyendo a acelerar la disminución de la abundancia. La reducción de los límites de captura de la flota de palangreros no bastó para frenar esta disminución. Además, los palangreros habían mejorado la eficacia de sus artes aumentando la distancia entre anzuelos, por lo que la medición hecha por la Comisión de la captura por unidad de esfuerzo desde 1960 resultó superior a la realidad. Los efectos de esta variación de los artes son enormes y es preciso evaluar de nuevo los parámetros fundamentales de las poblaciones de hipogloso. Aunque la pesquería ha cambiado notablemente y la Comisión ha perdido en parte el control, debido a las capturas accidentales de los arrastreros, se ha conseguido mantener una pesquería viable gracias al sacrificio de la flota de palangreros de América del Norte. La producción de esta pesquería esta ese peligro, porque no se controlan las capturas de las flotas de arrestreras y éstas siguen aumentando.

THE International Pacific Halibut Commission (IPHC) was established in 1923 by a Convention between Canada and the United States for the preservation of the halibut fishery of the North Pacific Ocean and the Bering Sea. The Convention was the first international agreement for joint management of a marine fishery. The Conventions of 1930 and 1937 extended the Commission's authority and the 1953 Convention specified that the halibut stocks be developed and maintained to produce the maximum sustained yield.

Three Commissioners are appointed by Canada and three by the United States. The Commissioners appoint the Director of Investigations who with his scientific staff collects and analyzes statistical and biological data needed to manage the halibut fishery. The Commissioners annually review the regulatory proposals made by the scientific staff and consider advice from the Conference Board that represents vessel owners and fishermen. The regulatory measures adopted by the Commission are submitted to the two governments for approval and the fishermen of both nations are required to observe the approved regulations.

The Commission has been proclaimed one of the few conservation agencies that have successfully managed a marine fishery. This FAO Conference on Fishery Management affords the opportunity to review the history of the Commission and the halibut fishery, to examine the reasons for the success of the management program, and to discuss current management problems.

History

THE CONVENTION

Bell (1969) described the negotiations that led to the Halibut Convention and reviewed the subsequent revisions and the Canadian and U.S. enabling legislation. Historically, agreements between Great Britain and the United States in the 1800s emphasized economic factors such as trade and reciprocal port privileges, and these aspects also were considered when Canada and the United States discussed conservation measures for halibut. After several unsuccessful attempts, a Convention was signed in 1923 that provided for a closed season and established the Commission. Later Conventions increased the authority of the Commission, which is now empowered to establish fishing seasons, limit the catch, institute size limits, regulate the type of gear, collect statistics, and conduct scientific studies on the halibut stocks. The Convention does not provide for allocation of the catch between member countries, nor does it authorize limitations of the number of vessels participating in the fishery.

THE FISHERY

Descriptions of the halibut fishery by Thompson and Freeman (1930) and Bell and St-Pierre (1970) distinguished three phases — the Indian fishery (through the 1800s), the early commercial fishery (1880–1920), and the recent longline fishery (after 1920). I will review three periods in the fishery since the establishment of the Commission. The earliest period (1923–30), though brief, was critical for the Commission; catches declined continually, diesel-powered schooners had been introduced, and gear and fishing methods were changing. Fishing from dories that delivered the catch to "mother-ships" was being replaced by longlining from the larger vessels, and with this change the spacing of hooks on the groundline was increased from 9 to 13 ft (2.7–4.0 m).

The second period started in 1930 when most of the fleet had converted to the new methods that were to dominate the fishery for the next 20 years. Over 90% of the fleet fished with 13-ft (4.0-m) hook-spacing, and electronic gear improved the vessels' effectiveness. The Commission was given greater authority and introduced more regulations. The catch and catch per unit of effort gradually increased.

During the third period, 1950 to date, changes in fishing techniques were gradual, but they consistently increased efficiency. Fishermen added more sophisticated electronic gear, including radar, which reduced searching time and allowed more precise coverage of the grounds. Different baits were tested to improve catching power. Changes in hook-spacing, that also increased the efficiency of the gear, began in the early 1950s, but the acceptance of wider-spaced gear was slow and not until the mid-1960s did the 18-ft (5.5-m) gear dominate the fleet. In the latter part of the decade, when stock abundance had been reduced substantially, the change to wider hook-spacing was accelerated and the fleet rapidly converted to 21-, 24-, and 26-ft gear (6.4-, 7.3-, and 7.9-m). These improvements brought about operational and economic advantages: the number of men per vessel decreased and the amount of gear fished per man increased (Table 1).

TABLE 1. Number of men per vessel and number of skates fished per man-day, 1940–70.

Year	No. of men per vessel[a]	No. of skates per man-day[b]
1940	10.97	4.6
1950	8.72	6.0
1960	7.44	7.1
1970	6.90	8.4

[a] Based on vessels from 40 to 60 net tons.
[b] Based on vessels fishing 40–60 skates per day.

Bell and St-Pierre (1970) showed that the average annual catch by 10-year periods had increased consistently since 1930, but their comparison combines the high catches of the early 1960s with the low catches of the late 1960s. A summary of annual catches by regions shows that since 1960 not only have total landings declined but catches in each region have also declined (Fig. 1). Stock abundance estimated by catch per unit effort (CPUE) also shows a decline for each area since 1960. As the abundance decreased the Commission reduced the catch limit, generally by 500 to 1000 metric tons a year. In 1972, a reduction of approximately 6000 tons was imposed after a reassessment of CPUE showed that stock abundance during the past decade had been overestimated (Skud 1972).

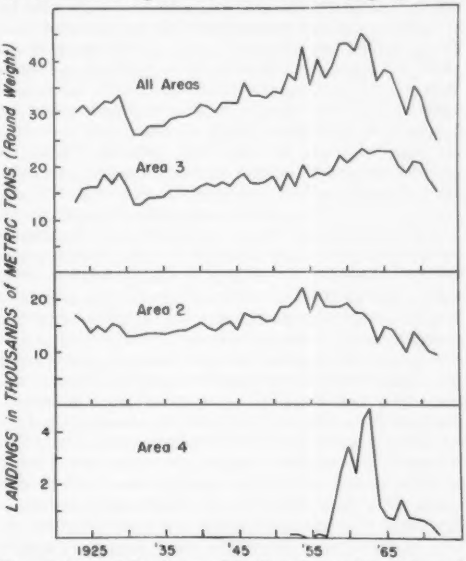

FIG. 1 Annual landings of halibut by regions: Area 2 (northwestern states, British Columbia, and southeastern Alaska); Area 3 (Gulf of Alaska and southern Aleutians); Area 4 (Bering Sea).

Management

Several investigations initiated by the Commission have become classic examples of fishery research, e.g. Thompson and Herrington (1930), Thompson and Van Cleve (1930), McEwen et al. (1930), Thompson et. al. (1931), Thompson and Bell (1934), and Thompson and Van Cleve (1936). These early works not only set a pattern for subsequent biological studies but may be said to have fathered oceanographic studies in the North Pacific. Moreover, these studies indicated a decline in abundance of the halibut stocks as a result of fishing and established the basis for IPHC's management program. The catch had dropped steadily through the 1920s, reaching minimum in 1930, but following the Commission's measures to limit the catch the abundance of the stocks increased. Regulation started with a closed winter season and, as greater authority was granted to the Commission, continued with closed nursery areas, gear restrictions, catch limits, and a minimum size limit. These measures, coupled with effective enforcement executed by the two member countries, gave IPHC the control necessary to manage the resource.

Scientists have disagreed as to the role of the Commission in revitalizing the halibut stocks, i.e. whether the increase in abundance resulted from the restriction of effort or was caused by environmental conditions (Burkenroad 1948; Thompson 1952; Ketchen 1956; and Bell and Pruter 1958); and economists contend that IPHC's regulations have reduced the efficiency of fishing and marketing (Crutchfield and Zellner 1962). Granting that early conservation measures may not have been as effective as initially purported and that economic inefficiencies exist, the maintenance of a viable fishery under intense exploitation for a 30-year period certainly speaks for the Commission's contribution. Many scientists have recognized IPHC's role as a classic example of fishery management based on scientific information, but individuals attribute the success of IPHC to different causes. Some credited IPHC's organizational structure, i.e. maintaining its own research staff, in contrast to other international groups that function through an Executive Secretary and draw on the research agencies of member countries. Others have concluded that IPHC simply had the good fortune to work on a long-lived species with an uncomplicated life history and a one-gear fishery. Still others contend that the success was achieved because the two member nations of IPHC have similar cultures and interests. Each of these views has some basis in fact, but I consider them rather simplistic. No single explanation can account for the success of IPHC, and one of the most important aspects has been virtually ignored — *control*! Having the scientific data is the basic need, but beyond that, to effect a management program an agency must have the authority to introduce the needed conservation measures and must be supported by adequate enforcement. The cooperation of fishermen also is needed and IPHC helped to engender this attitude by convincing industry of the benefits to be derived from the curtailment of effort.

The critical condition of the halibut fishery today is due, in part, to the loss of control of certain elements in the fishery; this situation is described in the following section.

Stock Decline Since 1960

An examination of the events of past years is necessary to understand the decline in the abundance of halibut that has occurred during the last decade. Before 1950 over 90% of the halibut catch was taken by the regular longline fleet (vessels over 5 net tons) and the incidental catch of halibut by other fisheries was small. During the 1960s important changes occurred and there were increases in: efficiency of the longline gear; percentage of the catch taken by small setline vessels and salmon trollers, particularly in British Columbia and southeastern Alaska; effort by domestic (Canadian and U.S.) trawlers; and effort by foreign trawlers from Japan and the USSR. (Effort by trawlers, foreign and domestic, is directed towards groundfish other than halibut, which are taken incidentally. IPHC prohibits the retention of halibut caught by domestic trawls, because the gear is selective for fish below the optimum harvesting size. Some mortality occurs even though the incidentally caught halibut are returned to the sea.) Other factors such as better bait, and increased catches by sportsmen, also contributed to greater removals from the halibut stocks, but these are less important. The role of natural factors — variations and trends in year-class strength — since 1960 have not been assessed.

The decline of the halibut stocks began when the effort by trawlers fishing for other groundfish was relatively low. Once the trawl fisheries expanded, however, exploitation by the longline fleet was greater than should have been permitted because quantitative measures of the removals by trawls were not available and because the loss in yield was not immediately detected by CPUE. When IPHC did reduce the catch limits, the reductions were not sufficient to compensate for the increased fishing mortality that resulted from the combined effort of longline exploitation and losses to other gears. The situation and the sequence of events that created it are described in the following paragraphs.

Canada, Japan, and the United States are parties to the International North Pacific Fisheries Commission (INPFC), and Japan has agreed to abstain from fishing North American halibut stocks that are fully utilized. IPHC contended that the major halibut stocks were being exploited at maximum levels. INPFC concluded that the evidence was not sufficient to support this position in the Bering Sea. In 1963 halibut was removed from the abstention list in the Bering Sea and INPFC established a quota in the Bering Sea for the longline fleets of Canada, Japan, and the United States. The catch was about 5000 metric tons in 1963 and about 3000 in 1964; it then fell rapidly and has been less than 500 tons for the last 3 years. Apparently the permitted catch was in excess of maximum sustained yield (MSY) and caused the decline. Failure of the stock to recover after catch limits were reduced has been compounded by the increased effort and incidental catch of halibut by Japanese and Soviet trawlers.

The decline of the Bering Sea halibut stocks also influenced stocks in the Gulf of Alaska (IPHC Area 3) because halibut migrate there from the Bering Sea. Halibut are also lost to foreign and domestic trawlers in Area 3, although the foreign trawling (for groundfish and shrimp) and domestic trawling (for shrimp) were not extensive before 1960. The CPUE of the North American longline fleet in Area 3 decreased from a maximum in 1960 by 30% in 1965, suggesting that the stock decline began before trawling was extensive. After 1965, when the full effect of the trawl losses occurred, CPUE continued to drop and is now about one-half of the 1960 level. In southeastern Alaska and British Columbia (IPHC Area 2), abundance was at a peak in 1952-53, earlier than in Area 3. CPUE in Area 2 had increased consistently and in 1953 was nearly 4 times that of 1930. By 1960 CPUE of the longline fleet in Area 2 had declined more than 30% from 1953, even though effort by domestic trawlers had been relatively stable and foreign effort was low.

IPHC had increased the removals in both Areas 2 and 3 to test the estimated MSY of the stocks. Catches in Area 2 exceeded MSY in the mid-1950s, and in Area 3 MSY was reached during the early 1960s. IPHC expected a decline in CPUE when the fishing intensity was increased, but the rate of decline was greater and lasted longer than anticipated. Changes in recruitment and environmental conditions may have contributed to the decline but the deliberate increase in setline fishing must be considered a major cause. In any case, since maximum CPUE was reached before the expansion of domestic and foreign trawling, it is doubtful that the trawl fisheries were responsible for this initial decline of the halibut stocks.

The decline in abundance of halibut has continued in the late 1960s, and with vastly increased trawl effort, domestic and foreign, the CPUE of the longline fleet has decreased to a level comparable to that of the early 1940s. Though IPHC gradually reduced the catch limits as CPUE declined, the stocks did not respond as anticipated, i.e. the reductions failed to arrest the decline in abundance. The losses to trawlers accelerated the decline initiated by the longline fleet, and apparently the total reduction in stock abundance was greater than originally estimated. In addition, fishermen had increased the effectiveness of their longline gear by increasing the spacing between the hooks, and as a result IPHC's estimate of abundance during the 1960s was too high (Skud 1972). To compensate for this change a more drastic reduction in the catch limit was necessary and was initiated in 1972. Without current catch and effort statistics from the domestic and foreign trawl fleets it is difficult to determine the precise level of catch required to halt the decline in abundance of the halibut stocks. Estimates of losses through the incidental catch of halibut by the trawl fisheries in past years are needed. Hoag (1971) estimated that the loss in yield (round weight) through the incidental catch of halibut by domestic trawlers in British Columbia is 1500-2000 metric tons annually. Similar studies are necessary to estimate the incidental loss to the domestic fisheries for shrimps and crabs in Area 3 and to foreign fleets in the Gulf of Alaska.

IPHC will attempt to maintain a viable longline fishery during the period of stock adjustment, but even greater reductions in catch limits may be necessary before recovery can be achieved. New problems have arisen coincident with the quota reduction in 1972; in particular, the price of halibut has doubled and this has attracted new entrants into the fishery, vastly increasing the available effort and influencing the economic structure of the fishery.

Future Assessments

The "simple" halibut fishery of yesteryear no longer exists, and recent studies indicate that former conditions were more complex than imagined. Future management of the halibut fishery demands a better understanding of the past as well as the present. The excellent data base maintained by the Commission will enable us to establish a new measure of CPUE and to study changes in fishing power needed to equate early and late years of the fishery. The effects of hook-spacing on CPUE and on the apparent growth of halibut must be reexamined, and the effect of changes in growth rate on CPUE must be considered. In addition, there is need to study the fluctuations in recruitment.

Though the fishery has changed measurably, and IPHC has lost some of its control owing to the incidental catch by trawlers, a viable fishery has been maintained through the sacrifice of yield by the North American longline fleet. Current information for assessment indicates that the North American fishery is in jeopardy because losses to trawl fleets are not controlled, and continue to increase.

Incidental catches in multispecies trawl fisheries are not peculiar to halibut. Other highly desirable species such as crabs, haddock, and lobsters – to name a few – are also taken as by-catches. These species are in great demand and usually are exploited at or near the maximum level for the resource. If these single-species fisheries are to be maintained, some means must be made to accommodate them by alleviating the problems created by multispecies fisheries. One approach would be to collate statistics of the catch with biological and economic data and systematically schedule the fishing operations to obtain optimal utilization from both fisheries. For example, Hoag (1971) showed that the by-catch of halibut by Canadian and United States trawlers changed with area and depth as well as by season and target species (groundfishes other than halibut actively sought by the trawl fleet). Data from large offshore trawlers indicate a similar variation in the by-catch of halibut. With proper timing and distribution of trawl effort, the by-catch of halibut could be substantially reduced, i.e. by restricting trawl fishing on specific grounds when by-catches are highest. At the same time, ample opportunity could be afforded for trawl fishing on other grounds so that the production by trawlers would not be seriously affected. Restricted grounds could be open to trawling when by-catches of halibut were low and the total catch of the target species on these grounds probably would not change significantly.

There is an urgent need for research on multispecies fisheries to determine whether adjustments in trawl effort (or other means) offer practical solutions to the problems of single-species fisheries and to insure the optimal use of all species.

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Report on Technical Session IV — Section 4

Stocks and Utilization

1. The North Pacific fisheries expanded rapidly after World War II. New areas were opened up and new species were attacked, while traditional fisheries were subjected to increased pressure. From 1955 to 1970 the total catch almost doubled: from 11.6 to 22.0 million tons.

TRAWL FISHERIES

2. Highlights of this development have been the rise and decline of trawl fisheries for Bering Sea flounders and for ocean perch along the North American coast, the large catches of hake taken from California to British Columbia, and especially the enormous amount of Alaska pollock taken from Japan to Kamchatka and in the Bering Sea. There has been a shift from industrial uses of these species in favour of human consumption. Some increase in landings of pollock may be possible, but no large increase in groundfish landings is anticipated. Another major trawl-fishery region is the East China and the Japan Sea, where several nations take part in an intensive fishery.

PELAGIC FISHERIES

3. Pelagic fisheries have had a checkered career, with serious declines registered for several major stocks of herring and sardines. The catches of such other species as anchovies, saury, mackerel, and squids have fluctuated, but in recent years their combined yield has been fairly steady. This suggests that a versatile fishing capability will be able to produce a good harvest in spite of variations in individual species.

4. The histories of North Pacific pelagic fish catches were compared with those of similar species in the North Atlantic. In the Atlantic there is a well documented history of herring fluctuations over several centuries, which must have been related to environmental factors because the fishery was then very weak. In the Pacific all of the collapses have occurred after a considerable intensity of fishing had been mounted, although in some cases it seems likely that the fishery could not have made the major contribution to the collapse.

5. Whatever the cause of such declines, it was pointed out that when a stock is at a very low ebb it is prudent to relieve it of any additional stress, if possible by stopping fishing completely. Stopping a fishery causes no great loss when abundance is extremely low, but the stage at which a reviving stock should first be exploited again is likely to be a subject of heated debate.

6. Expansion of pelagic fisheries would be possible in some areas, particularly for the very lightly-fished stocks off the Californias.

HALIBUT

7. The line fishery for halibut has been the subject of a bilateral agreement between Canada and the United States since 1924. Its purpose is to investigate and manage the stock, and the agreement includes no provision for dividing the catch or for limiting entry. After stabilization of the catch at a rather low depression level in 1931 the stock gradually increased, and after 10 years or so larger quotas became possible. With the developing trawl fishery in the area it became necessary to prohibit trawl landings of halibut in order to maintain control. With the post-war expansion of trawling and the appearance of major fleets in the eastern Pacific, the management picture became much more difficult. Even with the best of intentions it is difficult to avoid capturing and damaging some halibut when fishing in this manner. Recent stock levels of halibut have declined almost to those of 1931, as measured by catch per unit of longline gear adjusted for an increase in spacing between the hooks. It was suggested that greater protection might be afforded the longline fishery by designating areas and/or times when trawling would be prohibited.

SALMON

8. Asian salmon stocks had some respite during the war, but fishing was intensified immediately afterward, including a greatly increased oceanic fishery west of 175° W. Catches of Asian stocks have stabilized at levels much lower than the prewar peak catches. American salmon catches also are substantially less than those of the 1930s. Salmon management presents complex problems but it is essential to maintain adequate spawning escapement. Several international agreements exist where more than one country harvests a given stock.

9. In all of the major salmon countries fishing effort is regulated: by direct control in Japan and the USSR, by closures and quotas in the United States and Canada, including provision for equality of harvest between the countries for two species in one region. Canada is also reducing participation in salmon fishing by means of a "buy-back" program.

MARINE MAMMALS

10. The paper on marine mammals recorded a history of successes (fur seals) and failures (Antarctic whales) in the regulation. Instead of "failure," in the case of the fin whale it would perhaps be better to say a reprieve at the last moment. There is also new action in the form of a quota for Antarctic minke whales, on the basis of limited evidence. The quota will be revised as more data become available. Parallels and differences between the management of whales and fish were pointed out.

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The Industry

11. North Pacific fishes are harvested by a combination of local inshore fisheries and wide-ranging fleets. So far the only major conflict between the two has been with respect to salmon and some groundfishes. In general American fisheries are selective for high-value species, while Asian countries take whatever is available in quantity. This reflects mainly the great demand for fish in all Asian countries, as compared with more limited and eclectic markets in America.

Statistical Data

12. Statistical data for most fisheries are fairly good, and are excellent for some. The International North Pacific Fisheries Commission has been effective in bringing together statistics from member countries and some others. However, in some cases the interpretation of catch and effort statistics has become extremely difficult. This is because of rapid changes in the kinds and efficiencies of vessels and equipment, and because of changes in the principal target species. For example, it is not yet determined whether the abundance of Alaska pollock in the Bering Sea has decreased or increased since intensive fishing began.

International Agreements

13. No fewer than 15 international agreements exist among the nations of the North Pacific for the purpose of regulating their fisheries. However, only two of them are of the "open" type like the major Atlantic commissions; one of these concerns whales, and the Tropical Tuna Commission is rather peripheral to the North Pacific.

14. Negotiations among two or three parties on limited matters are of course easier than many-faceted general discussions involving many countries. However, a great proliferation of small agreements makes for excessive expenditures of time and duplication of effort. Also, it is impossible to undertake or coordinate really effective general research programs in this manner. The Commission that has sponsored the most comprehensive researches in this region is the North Pacific Fisheries Commission (Canada, Japan, and the United States). However, its work, though wide-ranging and varied, is focused on a narrow set of objectives related to "abstention."

15. At the moment the majority of the largest fisheries of the North Pacific are not subjected to formal international consideration. Thus, there seems a need for a comprehensive arrangement in this region, which might incorporate the research and possibly some other aspects of the various specialized agreements, though not at all. The effectiveness of such a new arrangement, however, was questioned by some participants.

FAO Technical Conference on Fishery Management and Development

TECHNICAL SESSION IV — SECTION 5

Regional and Other Case Studies — North Atlantic

CHAIRMAN: G. SAETERSDAL, NORWAY

Management and Developement of Fisheries in the North Atlantic[1]

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The "conventional" fish species of the North Atlantic are mostly being fully utilized or nearly so, some having been overexploited in recent years. Recommendations for management are made by the International Commission for the Northwest Atlantic Fisheries (ICNAF) and the North East Atlantic Fisheries Commission (NEAFC). The factual and conceptual basis for management is provided by the scientists of many nations, coordinated by ICNAF and by the International Council for the Exploration of the Sea (ICES). The need in nearly every major North Atlantic fishery is to limit fishing effort, which in practical terms means allocating quotas to states. Such action has been initiated by ICNAF and is under active consideration by NEAFC. The process would have been easier if it had been begun a few years earlier, before several major stocks became depressed, but since new ground is being broken internationally the delay was almost inevitable. Regulations of mesh size in trawls have been in force in both areas for some years. These were successful in providing a greater yield from each year-class of groundfish as it appeared, but could not by themselves ensure a breeding stock adequate for optimum reproduction. Problems of allocation of quotas, of enforcement, and of national claims for the extension of exclusive fishing zones will require continued discussion and goodwill among the nations in the years ahead.

La plupart des espèces traditionnelles de poisson de l'Atlantique Nord sont pleinement ou quasi pleinement utilisées, certaines ayant été surexploitées ces dernières années. La Commission internationale pour les pêcheries de l'Atlantique Nord-Ouest (CIPAN) et la Commission des pêcheries de l'Atlantique du Nord-Est (CPANE) ont recommandé des mesures d'aménagement. Les informations théoriques et pratiques de base pour l'aménagement sont fournies par les scientifiques de nombreux pays, coordonnées par la CIPAN et par le Conseil international pur l'exploration de la mer (CIEM). Dans presque toute importante pêcherie de l'Atlantique Nord, il est nécessaire de limiter l'effort de pêche, c'est-à-dire en pratique d'attribuer des contingents aux Etats. La CIPAN a la première appliqué de telles mesures, que la CPANE envisage sérieusement elle aussi de prendre. L'application de ces mesures aurait été plus facile si elle avait été entreprises quelques années plus tôt, avant l'épuisement de plusieurs stocks importants, mais l'étude, à l'échelon international, de nouvelles formules explique que ce retard ait été quasiment inévitable. Le maillage des chaluts est réglementé dans les deux zones depuis quelques années. Cela a permis d'augmenter le rendement de chaque classe d'âge de poisson de fond à mesure de son entrée dans la phase exploitable, mais n'a pas suffi à assurer un stock de géniteurs adéquat pour rendre la reproduction optimale. Divers problèmes (répartition des contingents, mise en oeuvre de la réglementation, et prétentions nationales à l'extension des zones de pêches exclusive) exigeront des discussions continues et de la bonne volonté de la part des nations a l'avenir.

La mayor parte de las especies de peces "tradicionales" del Atlántico Norte se explotan total o casi totalmente y algunas en demasía en los últimos años. La Comisión Internacional de Pesquerías del Atlántico Noroeste (CIPAN) y la Comisión de Pesquerías del Atlántico Nordeste (CPANE) han hecho recomendaciones para su reglamentación. Científicos de diversas naciones, coordinados por la CIPAN y por el Consejo Internacional para la Exploración del Mar (CIEM), han preparado las bases teóricas y prácticas para ello. Hay que limitar las actividades de pesca de casi todas las pesquerías importantes del Atlántico Norte, lo que prácticamente significa asignar cupos a los estados. La CIPAN ha iniciado tales medidas que la CPANE está estudiando activamente. El proceso hubiera sido más fácil de haberse iniciado hace unos años, antes de que hubieran mermado diversas especies importantes, pero, dado que internacionalmente se están abriendo nuevos horizontes, el retraso fue prácticamente inevitable. La reglamentación del tamaño de las redes de pesca de arrastre ha estado en vigor en ambas zonas durante algunos años. Con ello se lograron mayores rendimientos anuales de cada clase de pescado de fondo, pero no pudo por sí misma asegurar una cantidad

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suficiente de reproductores para alcanzar la reproducción óptima. Los problemas de asignar cupos, observancia coercitiva y las espiraciones nacionales para la ampliación de zonas exclusivas de pesca exigirán, en el futuro, una negociación continua y buena voluntad por parte de las naciones.

The North Atlantic as a Fishing Area

THE North Atlantic has been for centuries a major world fishing area. Catches reached almost 15 million tons in 1970, exceeded only by the 16.7 million tons caught in the North Pacific. Stocks in this area have long been intensively fished and scientifically investigated by the surrounding highly developed industrial countries. For "conventional" species (for example, cod, haddock, and herring), catches have already equalled and in some cases exceeded the potential. Prospects for increased catches exist now only for the "unconventional" species (see chart 1.3 in FAO's Atlas of the Living Resources of the Seas).

The development of catches in the North Atlantic is illustrated in Fig. 1 and 2. The increase in total catch from the Northwest Atlantic (Fig. 1) has been primarily due to the steady rise in cod catches, off Greenland, Labrador, and Newfoundland, and since 1962 sizable catches of silver hake have also contributed. The steeply rising portion of the curve has been caused by development of the herring fishery since 1965. The drastic decline in catches starting in 1969 is probably to be blamed on bad year-classes for cod off Greenland and Labrador and adverse ice conditions in these areas. This is probably true for the decline in herring catches as well. But in addition, there are clear signs that the drop in catches has been aggravated by overfishing.

The primary reasons for the rise and fluctuations in total catches in the Northeast Atlantic (Fig. 2) up to 1967 were the cod and herring catches. The good cod yields for 1955-56 came from the northeast Arctic area. This was also the year of the first peak for herring catches in the North Sea and for the Atlanto-Scandian stock. The sharp rise in catches since 1961 reflects development of the herring fishery on the Atlanto-Scandian stock, which was intensified to a previously unimaginable degree by introduction of the power block in purse seining ,and with the help of sonar. After the complete collapse of this herring fishery since 1968, the total catch was restored with astonishing rapidity following a shift to other species such as capelin, Norway pout, mackerel, and haddock, and by good cod catches.

STRUCTURE OF FISH STOCKS AND FISHERIES

Stocks of the various fish species in the North Atlantic are relatively clearly distinguishable in their distribution and movements, and hence can be fished for specifically. Thus, a number of specialized fisheries have evolved which usually operate throughout the year, or on a seasonal basis, on species such as cod, redfish, flatfishes, herring, and mackerel. Some of these fisheries have long traditions; they are associated with consumer habits, some of which are so strong that other more abundant

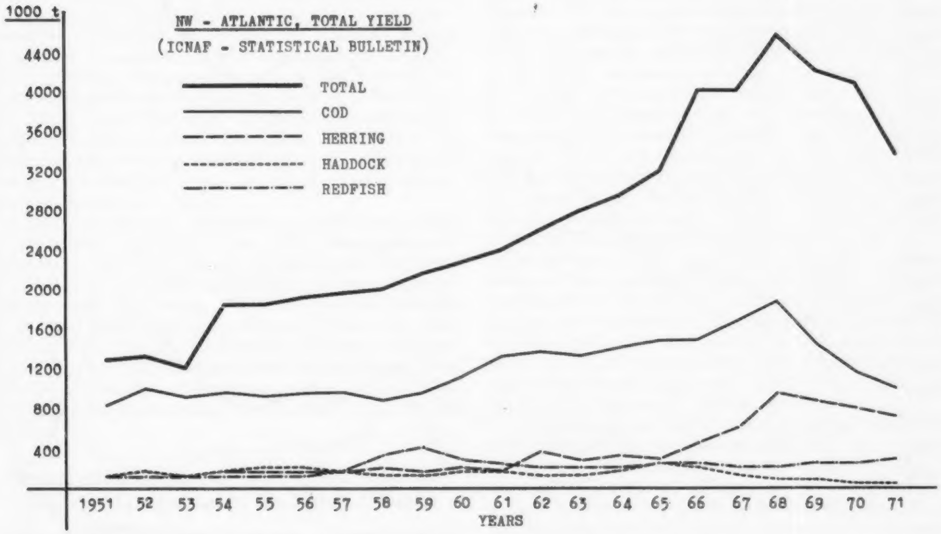

FIG. 1. Nominal catches in the ICNAF Convention Area, in thousands of metric tons.

species can hardly be disposed of on the market, and, although edible, are sold only for processing into fish meal.

STRUCTURE OF FISHING FLEETS BY VESSEL TYPES AND FISHING METHODS

Fishing fleets operating in the North Atlantic can be roughly grouped into three categories: inshore and coastal, medium-range, and deep-sea or long-distance, fisheries.

In the inshore and coastal waters of the North Atlantic many fisheries are worked by small vessels, using fixed gear, driftnets, trawls, purse seines, hooks, and the like. These fisheries are strongly bound to their normal grounds because the vessels have short operating ranges and fishermen often have second occupations on shore, in farming, or industry. The displacement of these vessels is usually not over 150 gross tons. There are no reliable figures on their number, but the current estimate is 40,000–50,000.

At the same time, almost every maritime state has a sizable number of medium-range fishing vessels, most of them of considerably under 500 gross tons, which can remain at sea for days and can carry out a wide range of fishing methods. These fleets, too, are largely bound to their regular fishing grounds, although some of them shift seasonally to distant coastal sectors (fishermen from southern Norway fish part of the time off the northern coast of that country, Baltic fishermen operate part of the time in the North Sea). These are mainly vessels landing fresh fish for human consumption or, particularly in Denmark and Norway, raw material for the fish meal industry. The vessels are owned mostly by individual fishermen, families, or small groups of associated fishermen. There are no comprehensive statistics for their number in the North Atlantic, but the estimate is 450.

The deep-sea or long-distance fisheries include about 620 ships. Some of them bring in fresh fish, and their operating range and the time they can remain at sea are limited to the 12–14 days that fresh catches will keep. About 400 of these vessels are almost exclusively trawlers of 500–900 gross tons. The last decade has seen the rise of the modern long-distance fishing fleets, which process fish into storable products either aboard the fishing vessels themselves or aboard mother ships. They can thus operate all over the world without dependence on bases, needing only a suitable port in which to transship their catches onto transports, refit, and change crews. Even these operations can be carried out at sea under appropriate conditions. As a rule these fleets work with bottom trawls and pelagic trawls, and some with purse seines.

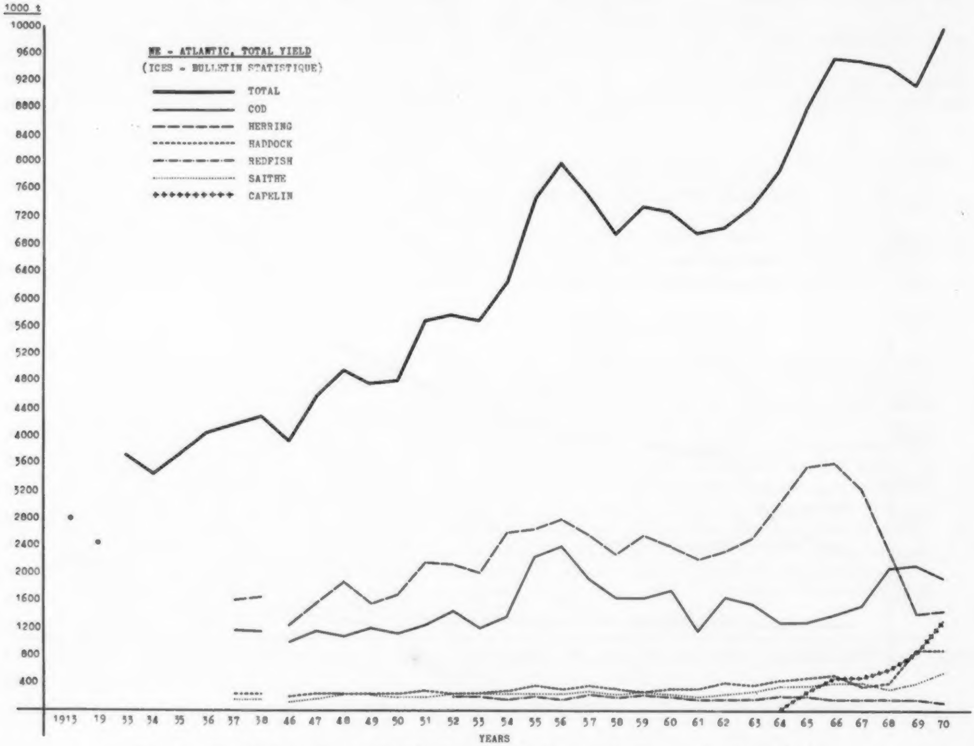

FIG. 2. Nominal catches in the Northeast Atlantic area, in thousands of metric tons.

Catches are frozen either in fillets or whole, or are canned. Offal and trash catches are processed on board into fish meal. The vessels are mostly owned by stock companies or are under state management. There is often considerable competition among fleets and fishing methods, and this has to be taken into account in managing the fisheries.

Fisheries in the North Atlantic are traditionally highly international. Fishermen from several European countries very early began to take cod off the North American coast, and in the Northeast Atlantic vessels from different countries have been fishing side by side for generations. Because of its geographical position, fishing in the North Sea cannot be anything but international, since none of the states claims more than a relatively narrow stretch of coastal water, and they have all recognized the principle of equal access for all to the living resources of the high seas and a collective responsibility for the preservation of the resources.

The common interest of the countries sharing the North Atlantic fishery led early to fishery agreements between countries, which served at first primarily to avert disputes among fishermen, particularly between trawlers and driftnet vessels — for example, the convention for the policing of the North Sea fisheries of 1882. On the other hand, by the turn of the century few international agreements had been concluded for conservation of fish, and they were confined to a few local inshore stocks. Fish resources of the high seas were then regarded as inexhaustible, and indeed they were in no jeopardy from the fish-catching capabilities of that time. The development of international cooperation therefore concentrated on promotion of fisheries. An important step in this direction was the foundation of the International Council for the Exploration of the Sea in 1902. Even then the member countries recognized the utility for practical fishing operations of comprehensive and systematic marine and fishery research. Because of the great size of the problem, it was not possible for any country by itself to investigate the physical and biological processes and their interrelations in extensive sea areas. They thus came to an understanding on international scientific cooperation, which has yielded rich fruits. Seventeen countries participate in this research today.

Broader multilateral cooperation toward conservation of fish stocks began in the late 1920s. Management of fisheries in the North Atlantic is now under the International Convention for the Northwest Atlantic Fisheries and the North East Atlantic Fisheries Convention described in other papers at this Conference. In addition, there is an agreement for the conservation of salmon stocks in the Baltic, to which Denmark, the Federal Republic of Germany, Poland, and Sweden are parties. A more comprehensive fishery agreement for the Baltic is under discussion.

Organization of International Cooperation for Fishery Management in the North Atlantic

North East Atlantic Fisheries Convention of January 24, 1959

International cooperation for the conservation and rational exploitation of fish resources in the Northeast Atlantic began with the international Convention for the Regulation of the Meshes of Fishing Nets and the Size Limits of Fish of March 23, 1937, signed by Belgium, Denmark, Germany, Iceland, Ireland, the Netherlands, Norway, Poland, Sweden, and the United Kingdom. This applied to the North Atlantic between 80°E long and 80°W long, and the equator. The agreement of 1937 contained, in addition to fish stock conservation measures (mesh regulations and fish size limits) as modified by the International Council for the Exploration of the Sea (ICES), elements of the North Sea Convention of 1882. Upon the outbreak of the war, however, this agreement became dead, and a wartime conference held in London in 1943 did not lead to any concrete results. The North Atlantic fish stocks recovered well during the war because little fishing was done during that time, and fishing operations begun in 1945 achieved outstanding results. With a view to guaranteeing optimum catches over the long term as well, in 1946 the British Government called a conference in London, during which the Convention for the Regulation of the Meshes of Fishing Nets and the Size Limits of Fish (the so-called Convention on Overfishing) was signed on April 5, 1946 by representatives of Belgium, Denmark, Ireland, France, Iceland, the Netherlands, Norway, Poland, Portugal, Spain, Sweden, and Great Britain. The area covered by this Convention was delimited to the west by 42°W long to meet the wishes of the USA, which felt that special measures were required to conserve the fish stocks in the Northwest Atlantic. Because of the protracted ratification process, it was only in 1953 that the Convention of 1946 finally became effective. Meanwhile, catches had already exceeded the optimum yield capacity of some stocks, and it became apparent that the Convention's measures (mesh regulations and minimum fish sizes) were insufficient to achieve optimum long-term yields. The member states therefore conferred on the content of a new Convention, and on January 24, 1959 signed the North East Atlantic Fisheries Convention in London. This new Convention became effective in 1963 and today is still the basis of international cooperation for the conservation of fish stocks in the Northeast Atlantic. Member states at present are: Belgium, Denmark, France, Federal Republic of Germany, Iceland, Ireland, the Netherlands, Norway, Poland, Portugal, Spain, Sweden, United Kingdom, and the USSR.

The purpose of this Convention, as stated in the preamble, is "the conservation of fish stocks and the rational exploitation of the fisheries which are of common concern to member states." The agreement extended the area covered by the Convention of 1946 southward to 36°N lat, and divided it into three regions (see FAO Map of the North Atlantic entitled "ICES, ICNAF, and NEAFC Fishing areas," October 1970).

For the purposes of the Convention, the North East Atlantic Fisheries Commission (NEAFC) was installed in London, to which every member state may appoint two commissioners and as many experts and advisers as it likes (Article 3). The Commission has a Chairman and two Vice-chairmen. It normally meets once a year. The Secretary and staff are provided by the British Ministry of Agriculture, on a part-time basis.

The Commission has three regional committees (Article 5). Participation in the fishery of a region confers membership on the committees. Membership is also open to countries with coastlines adjacent to the region or which elsewhere exploit stocks also fished in the region in question. The Commission can constitute other committees as needed, and it maintains permanent Finance and Enforcement Committees. Ad hoc working groups have frequently been formed over the years to deal with special problems, e.g. the herring fishery, mixed fishing, international control, and reduction of fishing intensity.

FINANCE

The Commission's budget is financed by a basic contribution of £200 per member state and additional amounts as required to cover the budget apportioned among the members in proportion to the number of their regional committee memberships (Article 4).

SCIENTIFIC COUNCIL

The International Council for Exploration of the Sea advises the Commission on scientific matters through its Liaison Committee, for which it receives a financial contribution from the NEAFC (1971–1972: £4750). The Commission also maintains a close working relationship with FAO, the OECD, and other international organizations (Article 11).

DUTIES AND POWERS (ARTICLE 6)

The Commission is required to keep under review the fisheries in the Northeast Atlantic, consider what measures may be required for the conservation and rational exploitation of the fish stocks, and make recommendations to contracting states with regard to the conservation measures set out in the Convention. Article 7 authorizes the Commission to recommend measures in relation to the following: mesh size and other fishing gear regulations; fish size limits; closed seasons and closed areas; measures for the improvement and increase of marine resources (including artificial propagation and transplantation); measures for regulating the amount of total catch and its apportionment among the member states during certain periods[2]; measures to regulate the amount of fishing effort and its apportionment among the member states in certain periods.[2]

Paragraph 2 of Article 7 empowers the Commission to recommend all other kinds of measures as well, although such proposals must be adopted by not less than a two-thirds majority, followed by acceptance by all contracting states.

As far as practicable, the Commission must base its recommendations on the results of scientific research and investigation (Article 6). Moreover, the Commission can consider social and technical aspects of fishery regulation, and in practice has to do so in any case. Moreover, the Commission may, by a two-thirds majority, make recommendations for measures of national control in the territories of the contracting states, and national and international measures of control on the high seas (Paragraph 3, Article 13).

RESOLUTION ON CONSERVATION MEASURES AND THEIR COMING INTO FORCE

The regional committees must keep fishing operations in their respective regions under review and propose conservation measures that may be necessary. Unlike ICNAF, however, proposals for fishery regulation need not issue from the regional committees. It is the Commission which decides in all cases. Except as otherwise expressly provided, decisions of the Commission are taken by simple majority vote. In cases of tied ballots, a proposal is taken as rejected. Every delegation has one vote.

The contracting states undertake to give effect to any recommendation made by the Commission and adopted by not less than a two-thirds majority of the delegations present and voting (Article 8); however, any contracting state may object to a recommendation within 90 days and thereby escape this obligation. In the event of an objection being made within the 90-day period, any other contracting state may similarly object at any time within a further period of 60 days. If objections are lodged by three or more contracting states, the recommendation is taken as not binding on any. After 2 years any contracting state may give notice of the termination of its acceptance of a recommendation that has become binding, and it may be joined in such notice of termination by any other contracting state. Other obligations of the contracting states are to provide all relevant information, to enforce regulations in their territorial waters, including the punishment of infractions.

International Convention for the Northwest Atlantic Fisheries of 1949

The Northwest Atlantic is one of the oldest fisheries in the western world. As early as 1497 Cabot reported that "the sea there is swarming with fish which can be taken not only with the net but also in baskets let down with a stone." Fishermen from North America as well as from several European countries have worked this fishery from earliest times. In 1580 more than 200 European vessels are reported to have fished there. Up to the turn of this century disputes between participating states related primarily to fishing rights, and less to problems of stock conservation. When representatives from 11 countries participating in the Northwest Atlantic fisheries met in Washington in 1949 at the invitation of the USA to conclude a convention on conservation measures, they did so less because of overexploitation of the fish stocks in the Northwest Atlantic than of overfishing in other sea areas. Thus, international cooperation toward the conservation and rational exploitation of fish stocks was begun in good time in the Northwest Atlantic.

The international convention was signed by the Governments of Canada, Denmark, France, Iceland, Italy, Newfoundland (now part of Canada), Norway, Portugal, Spain, Great Britain, and the USA on February 8, 1949, and became effective on 3 July 1950. By 27 January 1953 all the signatory Governments had ratified it. Since then the Federal Republic of Germany, the USSR, Poland, Romania, Japan, and Bulgaria have also joined, in that order.

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[2] A broadening of Article 7, paragraph 1 on these powers was proposed by the Commission in 1970 in accordance with Art. 7, para. 2 and presumably will become effective shortly.

Purpose of the Convention

The preamble to the International Convention for the Northwest Atlantic Fisheries of 1949 states that the contracting parties, sharing an interest in the conservation of the fishery resources of the Northwest Atlantic Ocean, wish to cooperate in the investigation, protection, and conservation of the fisheries in order to make possible the maintenance of a maximum sustained catch. The Convention area covers all waters off the east coast of North America from 39°N lat in the south to the Labrador area at 31°N lat in the north, and includes the waters off western Greenland as far as 78° 10′N lat. To the east the area borders on the NEAFC Convention area, at 42°W long. Its area is subdivided into five subareas.

For purposes of the Convention an International Commission for the Northwest Atlantic Fisheries (ICNAF) was established, whose headquarters are in Dartmouth, Nova Scotia. Every member government may appoint three commissioners, who may be accompanied by any number of experts or advisers. Every contracting government has one vote. The Commission has a Chairman, a Vice-Chairman, an Executive Secretary, and staff. It holds one regular meeting each year.

Committees — The Commission maintains the following standing committees: six panels — one for each subarea, and one for harp and hood seals in the whole Convention area. Representation on a panel is determined by participation in the fishery; countries with coastlines adjacent to a subarea have the right of representation on this panel. In earlier years representation was based on participation in exploitation of specific species; development of fisheries for other species — herring, for example — showed up the absurdity of this limitation, which was therefore dropped.

Finance and Administration — five members.

Research and Statistics — all contracting states, and observers from FAO and ICES (the duties of this committee will be described below).

Regulatory measures — all contracting states and observers from FAO, ICES, and NEAFC. The duties of this committee are: to consider possible measures for the regulation of fishing in relation to the stocks of fish, or of any particular species of fish in the Convention area or any part thereof; to consider the economic and administrative problems involved in the application of such measures, and in consultation with the Standing Committee on Research and Statistics, the scientific and statistical information required for their solution; to make appropriate recommendations to the Commission.

The Commission may establish other committees as required. The Convention provides that each contracting state may set up its own advisory committee composed of fishermen, vessel owners, and other interested parties, and whose representative may attend ICNAF meetings as members of the national delegations (Article V).

Financing

There is a basic contribution of $500 from each contracting government. The remainder of the sum required to cover the administrative budget is divided into a number of equal shares corresponding to the total number of panel memberships.

Scientific Advisory Services

The research required for the conservation of fish stocks is carried out by individual contracting states. Research plans are coordinated and results are discussed and evaluated in the Standing Committee on Research and Statistics. This committee meets yearly immediately before the session of the Commission, and writes a report for it. The functions of the committee are described in Article VI of the Convention as follows:

". . . obtaining and collating the information necessary for maintaining those stocks of fish which support international fisheries in the Convention area. The Commission may, through or in collaboration with agencies of the Contracting Governments or other public or private agencies and organizations or, when necessary, independently:

(a) make investigations into the abundance, life history and ecology of any species of aquatic life;

(b) collect and analyse statistical information relating to the current conditions and trends of the fishery resources;

(c) study and appraise information concerning the methods for maintaining and increasing stocks of fish;

(d) hold or arrange hearings in connection with the development of complete factual information necessary to carry out the provisions of the Convention;

(e) conduct fishing operations for purposes of scientific investigation;

(f) publish or otherwise disseminate reports of its findings, and statistical, scientific, and other relevant information."

The Rules of Procedure define these tasks further, saying that the Committee shall

"(a) recommend to the Commission policies and procedures in the field of statistics to ensure that complete, current and equivalent statistics are available at all times;

(b) keep under continuous review the research programmes in progress in the Convention area and adjacent waters, and make recommendations relating to research programmes.

(c) keep under review the state of fish stocks and the effects of fishing and provide the Commission and panels with regular assessments."

Functions and Powers of ICNAF

In addition to the scientific functions described above, the Commission conveys proposals for joint action to conserve stocks of those species of fish which support international fisheries in the Convention area (Article VIII). The original text of the Convention itemized the following possible measures: establishing open and closed seasons; closing to fishing such areas as are found to be spawning areas or to be populated by small or immature fish; establishing fish size limits; prescribing the fishing gear (e.g. minimum mesh sizes); prescribing an overall catch limit for any species of fish.

However, these powers proved over the years to be insufficient. Because of the tedious procedure for amendment of the Convention, they have been supplanted by the following general clause, which became effective on December 15, 1971:

"The Commission may, on the recommendations of one or more Panels, and on the basis of scientific investigations and economic and technical considerations, transmit to the Depositary Government appropriate proposals for joint action by the Contracting Governments, designed to achieve the optimum utilization of the stocks of those species of fish which support international fisheries in the Convention area." This clause gives the Commission the latitude to recommend any measure that it regards as appropriate in any situation. This appears advisable because the rapid development of fishing technique and the continuous change in fish stocks make it almost impossible to anticipate measures that will come under consideration in the future.

Unlike NEAFC, in ICNAF it is in the panels where proposals for conservation measures must be initiated. The Commission can only transmit panel recommendations as proposals with modifications and suggestions through the Depositary Government to the Contracting Governments, or refer them back to the Panel (Article VIII-2). If the Commission is unable to adopt a recommendation reaffirmed by a panel, the Commission must still forward it to the Contracting Governments (Articles VIII-3 and 4). The Commission may also make, on its own, proposals for the Convention area as a whole, and/or national and international measures of control.

IMPLEMENTATION

Originally, a proposal of the Commission had to be expressly approved by all the states members of the Panel for the subarea to which the proposal applied. This often led to considerable delays. Accordingly, the Convention was amended in 1964 to the effect that, as in NEAFC, proposals were to become automatically binding if not objected to within a given period of time. This provision became effective on December 19, 1969.

OTHER OBLIGATIONS OF THE CONTRACTING STATES

Contracting Governments must report the actions taken on enforcement of regulations on their citizens (Article XII).

The Contracting Governments agree to invite the attention of third countries to matters relating to fishing activities of such countries in the Convention area which adversely affect operations of the Commission.

COOPERATION WITH OTHER INTERNATIONAL ORGANIZATIONS

According to Article X of the Convention, the Commission must maintain working arrangements with related international organizations, particularly FAO and ICES. In practice there is also a close working relationship with NEAFC. The idea to bring ICNAF within the framework of a specialized agency of the United Nations (Article X-2) has been dropped.

Structure and Functioning of NEAFC and ICNAF: Comparison and Evaluation

There is a basic difference between ICNAF and NEAFC in regard to scientific investigation and advisory services. International cooperation in marine and fishery research in the Northeast Atlantic goes back to establishment of the International Council for the Exploration of the Sea (ICES). When, as a result of increasingly intensive fishing, problems of fish stock conservation had become urgent and measures of administrative regulation had become necessary, it was decided to set up a specialized agency to attend to these matters. A critical factor in this was the fact that ICES contracting states were not affected by these fishery problems in the same way. Besides, the loose legal form of ICES, which for many years had been grounded on a kind of gentlemen's agreement among the contracting states, was unsuited for the taking of decisions on binding conservation measures and their implementation. It was natural, however, to turn to ICES for the scientific basis of the administrative measure. This separation of scientific and administrative cooperation has the advantage that ICES carries out its research program entirely independently of current conservation problems, and can let itself be governed primarily by scientific considerations. It was this independence that made possible the great scientific prestige and achievements of ICES. On the other hand, the Council has never hesitated to give its full attention to problems presented to it by the Fishery Commission or to point on its own account to urgent conservation problems and possible solutions for them. In this regard the operation of the Council is highly flexible and efficient. For special problems, working parties are set up, in which experts of the contracting states meet between the yearly sessions. The ICES Liaison Committee to NEAFC transmits questions of practical administration and, conversely, in its advisory functions can draw on the full range of scientific work done by ICES. Another major advantage is that close cooperation among scientists of the contracting states enables the Liaison Committee to prepare its report on stock assessments, effects of fishing operations and conservation measures, and answers to other special questions posed by NEAFC, so well in advance of meetings that the commissioners have ample time and opportunity to evaluate them on the national level and take them into account in preparing for the annual meetings.

In ICNAF the technical discussions and deliberations of the commissioners are packed into the relatively short duration of the annual meeting. It is only in the last few years that the report of the Committee on Research and Statistics has been finished in time for the opening of the Commission's plenary sessions. Another problem in opinion formation within ICNAF is the circumstance that the Committee for Research and Statistics has to evaluate and discuss a flood of papers from individual workers for the annual meetings, whereas in ICES positions on special problems are as a rule jointly hammered out in working parties in advance. However, scientists of the ICNAF contracting states have also shifted increasingly to the procedure of considering individual problems in special sessions — often jointly with ICES:

When comparing the modes of operation of ICNAF and ICES, it must be laid to the credit of the ICNAF that its efforts have more bearing on practical problems, and its technical data and analyses are often of greater immediate interest. One reason for this is that in ICNAF administrative and technical functions are combined on an organizationally sound basis with a view to the task in hand, and because the tasks assigned are more narrowly delimited.

On the other hand, separation of technical and administrative functions has the advantage that scientific questions can be posed more freely and be treated and discussed in a broader setting. The cooperation of fishery biologists, hydrographers, ichthyologists, and other oceanographers in ICES is a source of stimulation to investigators in the separate fields. Fishery research cannot afford to despense with the other branches of oceanography because it must always approach the sea in its totality as the habitat of the fish, for there is scarcely any hydrographical, chemical, or biological parameter that does not influence fish stocks in some crucial way. Finally, a larger, independent scientific organization can present its views to the Commission more authoritatively than a committee of a commission.

For the North Atlantic the most appropriate course might be to merge the scientific work of ICES and ICNAF, particularly since it has been found that there are multiple reciprocal fishery biology relations between the Northeast and Northwest Atlantic, the scientific problems are often similar, and a useful cooperation has arisen between ICES and ICNAF that could become more fruitful if all branches of oceanography were the more fully involved in it. Moreover, on the longer term, the North Atlantic regulatory bodies could be administratively unified, or could at least work closer together.

Separation of research on and regulation of fisheries is no panacea for all sea areas, however. For regions in which there is not yet international cooperation in oceanography and fishery research, but where action is urgently needed to regulate the fishery, the organizational form of ICNAF may be most conducive to the immediate achievement of effective and scientifically sound fishery regulation.

ICNAF and NEAFC work similarly in the performance of their administrative functions. But the conduct of ICNAF's annual meetings is complicated by the large number of its standing committees, and the requirement that proposals for regulatory action be initiated in the panels. The similarities of the problems confronting the panels led ICNAF to institute the practice of holding joint meetings of panels from time to time. In contrast, NEAFC decided at the outset that it would convoke the regional committees to separate consultations only at the wish of commission members, or if the matter in question appeared to necessitate doing so. Both commissions have found it advisable to deal with special problems in ad hoc committees, and even outside the annual meetings if need be. Only in this way was it possible, for example, to work out the international control system and the quota regulations.

The need in almost every major North Atlantic fishery to limit fishing effort and to allot specified fishing effort units or catch limits to the contracting states while also considering economic and technical aspects, is increasingly confronting the commissions with problems whose solution is not provided for in the Conventions, and which, in the last analysis, are essentially political issues. For example, when restricting a fishery it is hard to imagine that objective and universally valid criteria could be established for deciding the extent to which account is to be taken of the special interests of a coastal state, or of a state that wishes to expand its fishery. To solve these problems it was proposed that the powers of the Commission be broadened (as those of ICNAF already have been), and that majority decisions be allowed. It appears doubtful, however, whether this will make it any easier to reach appropriate solutions, or whether such a procedure is conducive to trustful cooperation among the contracting parties. In the past whenever major decisions on conservation measures failed to materialize — or materialized too late — this was usually due less to any inadequacy of the Commission's powers than to insufficient readiness of the countries concerned to accept the required measures or to find a compromise. The powers of ICNAF and NEAFC are today so all-embracing that if member states are determined enough any conservation measure could be approved and implemented.

One thing that member states could do would be to give their commissioners more latitude. Another thing would be to ensure that policy-making government representatives and special interest groups of the fish industry are consulted, and made aware of the need for the settlements and compromises involved. Better preparation on the national level would enable the commissions to arrive at the required decisions more quickly. That this is possible, even if some political pressure is required, is shown by the recent quota assignments of ICNAF. Sometimes, however, the conflicting viewpoints of the member states are so divergent, or the interests of individual states so greatly affected, that a policy decision must be sought on a higher level, as NEAFC attempted to obtain in December 1971. However, the actions of ministers should be limited to weighty decisions of principle, so that differences of opinion must be thoroughly sifted in advance, and enough alternative decisions and combinations of decisions worked out to facilitate a compromise on policy among ministers. Here there is room for package decisions, in which a country on which one arrangement imposes special sacrifices can be accorded compensatory advantages under another arrangement.

NEAFC and ICNAF Fishery Management: Problems and Solutions

PROBLEMS OF MESH SIZE REGULATION

The first recommendations made by either commission related to mesh size regulation. Given the fishing effort at that time it appeared that these measures would suffice to secure optimum long-run yields from existing stocks. The commissions were in the fortunate position that the two most vulnerable fish stocks — cod and haddock — lent themselves to mesh size regulation because there was a fishery directed specifically at them. Only in later years did it become apparent for other fisheries, herring for example, that mesh size regulation made little sense and other measures had to be considered.

A major problem in introducing mesh size regulations was to convince fishermen of the utility of such measures. Even today many fishermen think the best catches are made with the smallest meshes because then the fewest fish escape. Even though fishermen know that the fish which escape grow heavier, they look on these as a loss to themselves, with some other fishermen catching them later. Accordingly, the governments of the member states have made a considerable educational effort in talks, publications, and films. Because of fishermen's resistance, minimum mesh sizes were raised in small steps, although science could convincingly demonstrate that increasing the mesh size would lead to only relatively low immediate losses, but that these would often not even be apparent because the larger mesh nets cause less congestion and allow higher towing speeds, and thus could yield better catches. The reports of the meetings show, however, that in many cases the commissioners themselves could not make up their minds to increase mesh sizes because they could not believe that the escape through large mesh nets represented anything but loss to the fisheries of their countries.

Another problem was to determine the right mesh size. It often happens that the size of fish (and therefore the size of mesh needed to catch them) which maximizes long-term yields is different from marketable size. In many countries small cod, whiting, haddock, and sole fetch better prices than larger specimens. In such situations it was necessary either to allow the fish to grow at least long enough to reproduce once, or to minimize the taking of smaller sizes. The record so far shows that in most instances the commissions have given preference to economic interests. And hence biologists have been asking with increasing frequency whether it is not important to influence consumer habits by advertising and information work. There are examples to show that this can be done. In the Federal Republic skilful advertising elevated the redfish to the status of an esteemed food fish. When it became difficult in the Federal Republic to supply North Sea herring in the familiar sizes, the consumer was awakened by education to the palatability of the considerably larger Atlanto-Scandian herring.

Other problems hindered the introduction of mesh sizes that were optimal from the standpoint of biology of the fishes. Thus, when mesh sizes over 130 mm were used for redfish, large numbers of fish remained enmeshed in the nets, and this drastically changed their selectivity. Moreover, removing these fish is toilsome. This is one of the main reasons why mesh sizes have not been increased further in NEAFC Region I and ICNAF subareas 1 and 2.

Differential selectivity — The differential selectivity of different netting materials has long engaged the attention of the commissions. When ICNAF and NEAFC went into operation, trawling was done mainly with nets made of sisal, manila, and hemp, but in the years that followed, a whole series of stronger and more durable synthetic nettings came into use. It was found in controlled experiments that nets of synthetic material are more selective than nets of the same mesh made of natural fibers. It was therefore requested that differentials be established for synthetic nettings. Instead of taking advantage of the improved selectivity as an additional conservation effect, the commissions acquiesced in these demands and authorized smaller mesh sizes for synthetic nets than for sisal nets. As the use of synthetic nettings becomes more widespread, it is to be hoped that the practical significance of these differentials will fade, and that no more time will be wasted discussing them.

Gear that reduces net selectivity — Every increase in mesh size heightens the temptation for fishermen to tamper with nets in some way to make them less selective. The range of possibilities is wide, running from the rig of the net to the use of double cod ends. These devices are prohibited; however, there are others that are operationally necessary or which make sense, such as those that prevent the cod end from bursting during heaving, or the net from trailing on the sea bottom and tearing. An example of the latter is the attachment of ox-hides to the underside of the cod end of a trawl. In fishing on steeply sloping shelf ledges there is also the danger of the cod end rolling over sideways and the top side dragging on the bottom and tearing; in such cases the fisherman protects the net by tying old netting on the cod end. However, such kinds of protection of the cod end can greatly diminish its selectivity. The commissions have therefore permitted the use of certain types of protective devices that have been shown by scientific trials not to limit selectivity. But since in most cases such a device on the top side of the cod end is not attached until the vessel is at sea it is difficult to take action to ensure that the requirements are observed.

PROBLEM OF LIMITING SCOPE OF MESH SIZE REGULATIONS IN MIXED FISHERIES

The important and vulnerable cod and haddock stocks in the North Atlantic lend themselves well to mesh size regulation. But there are other species of fish which can be caught only with small mesh nets because of their size and shape and for which protection by mesh size regulation is not feasible. Whereas ICNAF has laid down mesh size prescriptions only for the taking of certain vulnerable species, thus leaving its members free to catch other species with small mesh nets, NEAFC has forbidden all use of small mesh nets and even their being carried on board, and authorizes their use only by special permission, for certain species. In these small mesh net fisheries, protected species are occasionally taken incidentally, and fishermen can then fall into the temptation of using small mesh nets to catch protected species, since these usually are more valuable. To avert this NEAFC has always refused to include in its exceptions for the use of small mesh nets, species that occur predominantly in association with protected species. Moreover, both commissions have enacted incidental catch regulations for small mesh net fisheries according to which vessels fishing with such nets may retain protected fish species on board only in certain quantities or in certain percentages (usually 10%) of the catch. To avoid hardships, in certain cases ICNAF allows this percentage to be computed over a period of 12 months.

In order to separate more clearly fishing for protected species with prescribed mesh sizes from fishing with small mesh nets, and to facilitate control, NEAFC has established a maximum mesh size of 50 mm for small mesh net fisheries, to prevent use of nets of between 50 and 80 mm (or 130 mm). Moreover, NEAFC regulations forbid any vessel fishing for protected species from carrying on board any small mesh nets at all. This requirement has led to difficulties as the operating range of the trawler has widened, because some vessels fish in both the Northeast and the Northwest Atlantic on the same cruise, and market demand makes it useful to catch more than one species — herring as well as cod and haddock for example.

Minimum Fish Sizes

As a supplement to its mesh size regulations NEAFC has established minimum fish sizes that correspond roughly to the prescribed mesh sizes. This is supposed to prevent fishermen from operating in areas mainly populated by juvenile fish, because in areas where most of the prospective catch is of juveniles, even nets of prescribed mesh can retain large numbers of small fish. To be sure, from the biological and economic standpoints, the requirement to discard undersized fish is of doubtful value because when they come on board they are usually already dead or are beyond reviving. This is why ICNAF has not established minimum fish sizes. Such a regulation is hard to enforce on the larger trawlers because most of them are equipped with fish meal plants, or else the fish are filleted and frozen in blocks. Accordingly, minimum fish sizes can be enforced only in the fresh fish landings of vessels that carry no processing equipment. A ban on fish meal plants aboard trawlers is occasionally requested, but this has been rightly rejected because it would be economically unreasonable to throw offal and trash fish overboard; moreover, doing so could heavily pollute the fishing ground.

Control of Regulatory Measures

NEAFC and ICNAF were aware from the beginning that, however much effort was spent to educate fishermen on the purpose of mesh sizes, they would still be strongly tempted to violate mesh regulations hoping to obtain larger catches. To thwart this, the Commission for the Northeast Atlantic at the outset tied its mesh requirements to minimum sizes for the protected fish species. Confidential scientific inquiries into the mesh sizes actually used by fishermen have revealed only imperfect observance of the mesh provisions during the first years following their introduction. In consequence, the two commissions recommended to their member countries augmented controls at sea and, moreover, they worked for the introduction of international net controls on the high seas. After protracted consultations, schemes of joint inspection were instituted for both the Northeast and Northwest Atlantic in 1971. Under these schemes the member countries designate specially authorized inspectors, and the names of the vessels from which they are to operate. They are issued with standard certificates, and the vessels from which they function must fly a special pennant. These officials may stop fishing vessels, board them and inspect their nets and catches. When an inspection has been carried out a report must be written on a standard form for transmittal to the Commission and to the government of the country under whose flag the vessel operates, as a basis for the possible punishment of infractions by that government. This is not true international inspection in the name and under the responsibility of the Commission, but is reciprocal inspection, under which every member state acquiesces in the inspection of its vessels by officials of another member state under specifically covenanted rules. The prosecution and punishment of violations remains in the province of the country of registry. The powers of the officials and the inspection procedure are described in detail in order to prevent abuses and controversies. This has also been necessary to enable the member countries to institute proceedings on the basis of the inspection reports.

The consultations on the Scheme of Joint Enforcement were protracted because the commissions were breaking new ground in international law. It had been up to then unthinkable for most countries that ships flying their flags could be subject to inspection on the high seas by officials of other countries. Only the few member nations of the 1882 convention for policing the North Sea fishery had experience of similar inspection of their vessels, but this was almost never carried out in practice. In the consultations the following main problems emerged:

Several member countries maintained no special inspection vessels. This gave rise to the question of whether officials could also carry out inspections from fishing vessels. The question was answered in the affirmative because advance notice would have to be given of the inspection and of the vessels on which the inspectors would sail.

In most countries vessels were regarded exactly like homes ashore in that they could be searched only under special conditions. This made it difficult for some member states to agree to inspection belowdecks. They raised the question of whether it would not be enough to limit inspection to recently used fishing gear and to the catch on deck. In the interest of maximum effectiveness of inspections, however, the majority of member states supported inspection belowdecks as well. But some member states accepted the Scheme of Joint Enforcement only with the reservation that inspection belowdecks be excluded, nor do these countries inspect any more thoroughly the vessels of other member countries.

Since large trawlers which operate in more than one sea area usually have numbers of different nets aboard, there was a long discussion of whether inspectors could look at all the nets aboard or only at those that had just been used. In NEAFC it was finally agreed that dry nets stowed belowdecks could not be inspected, whereas in the ICNAF area all nets could be.

The consultations also brought out that different ways of measuring mesh sizes were in use in different countries, some measurements being made under pressure and some not. Since the Northeast Atlantic Fisheries Convention merely says that a flat gauge with parallel sides must pass easily through the meshes, it was agreed that in doubtful cases this requirement was fulfilled if the gauge would pass through with a 5-kg weight suspended from it.

Evaluation — The Agreement on the Scheme of Joint Enforcement in the Northeast and Northwest Atlantic was the first major breakthrough of the commissions toward more stringent direct control of North Atlantic fisheries. The fact that in the Northeast Atlantic 14 states and in the Northwest Atlantic 16 states, with widely diverging economic and political systems have submitted their fishing fleets to far-reaching powers of inspection by other member states is to be credited to the cooperation that has developed in the activity over many years and to the resolve of the countries concerned to take drastic action for conservation and rational exploitation of fish stocks. Reciprocal inspection also helps dispel among fishermen the suspicion that other member governments are not as strict as their own. Above all, there is now more assurance that the measures recommended by the commissions for regulation on the high seas will really be observed. Moreover, this understanding on mutual control measures was for many member states the key precondition to their acquiescence in more severe fishery restrictions. While the Scheme of Joint Enforcement focuses on the control of mesh sizes and minimum fish sizes, it could easily be extended to encompass other measures such as closed areas, closed seasons, and other limitations on fishing effort.

The way in which the commissions arrived at their understanding for introduction of reciprocal controls – by tenacious exertion to solve all open or controversial problems and not to evade them or put them off — was a good rehearsal for treatment of other major problems that the commissions saw before them.

Measures to Regulate Fishing Intensity

When the 1946 Convention for the Regulation of the Meshes of Fishing Nets and the Size Limits of Fish finally went into force in 1953, it was already becoming apparent that even if mesh sizes were drastically enlarged these measures alone would not suffice to ensure an optimal and rational exploitation of stocks in the Northeast Atlantic. This realization led to the Fishery Convention of 1958, which broadened the powers of the Commission accordingly. The Convention of 1949 for the Northwest Atlantic had provided in its original text for establishment of overall catch limits. At first, ICNAF and NEAFC were fully occupied with application and enforcement of mesh requirements, and concentrated their efforts on introduction of the Scheme of Joint Enforcement.

Fishing intensity was constantly rising in the North Atlantic while the catch per unit effort was steadily diminishing in several areas, and in the second half of the 1960s scientists of the commissions reckoned that current catches in several major fisheries could be obtained with about half the fishing effort. In 1966–67 the commissions began jointly, and with FAO participation, to explore a general basis for fishing effort regulations. The ICNAF Committee on Regulatory Measures and the NEAFC ad hoc Study Group then discussed all aspects of fishing effort regulations, some of which were: determination of catch limits; fishing effort with which they could be taken; how standard fishing effort units could be defined for the various fishing methods and vessels; basis on which permissible effort was to be apportioned among member states; economic factors to be considered in fishing effort regulations; scientific information required for decisions on such regulations; and how to obtain it.

The economic aspects and questions relating to definition and establishment of fishing effort units were discussed in detail and then dropped. This could have been because of the manifest economic advantage of a reduction in effort, that is, the possibility of obtaining current catches with a fraction of the fishing effort. It was virtually impossible for the commissions to settle the special economic and social problems of effort regulation for all member states, a total of 20 countries with highly divergent political, economic, and social structures. In addition, decisions would have to be taken concerning such questions as the amount of fishing capacity to be left in service and the disposition to be made of excess capacity (vessels, crews, and associated shore installations). There was also the question of whether it would make economic sense to endow a small fleet with the highest possible fishing and profit-making capacity, or to allow a larger fleet to operate at the margin of profitability. Even within the same country, these questions often have to be answered differently for different regions or fish species. Thus, it has been shown in almost every member country that smaller fishing vessels with smaller crews and less rigid fishing methods can still make a profit in areas where larger trawlers can no longer be profitably operated. However, there are considerable differences in the operating costs of comparable fleets of different countries, and standard criteria for the Northeast and Northwest Atlantic would therefore be illusory. The business of defining fishing effort units, the associated categorizing of countless types of fishing vessels, and the assigning of effort units to the member states, appeared to most of the commissioners too complicated and encumbered with uncertainties, and statistical data and scientific knowledge were largely lacking. It was logical, therefore, that the commissions should soon agree to steer first for a catch limit system in which the aggregate limits were apportioned among the member states. It should then be left to the states to decide how they would have these limits taken by their fleets. The idea of an aggregate limit without apportionment among the member states was rejected for the major international fisheries because experience in the Pacific halibut fishery showed this course would probably lead to an uneconomic run by the fishing fleets on that limit.

The possibility of limiting fishing effort in certain areas by introducing closed seasons was used only as an emergency measure (because the powers were still lacking) for the herring fishery in the North Sea, but not used for other fisheries on technical and economic considerations (to keep the fleet occupied and the market continuously supplied).

In regard to the question of the extent to which fishing mortality of a stock must be reduced to achieve optimum long-run yields, i.e. what quantities could still be taken, a question of fundamental importance for the proposed catch limit regulations (and indeed of any regulation of fishing effort or fishing intensity), ICNAF and NEAFC found themselves in the fortunate position that their scientific consultative bodies (Standing Committee on Research and Statistics, and Liaison Committee) were able to supply for the worst-threatened stocks sufficiently reliable and complete data on the biological parameters relating to recruitment, growth rate, and natural mortality rate, i.e. estimates of the relative abundance of recruits; pattern of recruitment to each component of the fishery; fishing and natural mortality rate; and increase in weight and mean weight of successive year-classes.

The commissions also had computations based on models, from which it was possible to deduce the time and degree in which stocks would replenish themselves at different catch limits, and the long-run yields to be expected. Thus, there was no reason to put off restricting fishing intensity for lack of scientific data.

In regard to apportioning the permissible overall catch among the member countries, it was widely agreed that the decisive criterion should be the relative sizes of the current catches of the countries concerned. There then arose a protracted discussion over how long the reference period should be. Countries that had recently developed their fisheries asked for a short period, 3–5 years. Others that had taken relatively large catches in earlier years, but whose fleets had been reduced by diminishing yields, requested correspondingly longer reference periods. They argued that a short reference period would reward those who had contributed to the decline of the fishery. A variety of compromise formulas was evolved for the resolution of this conflict. For example, catches over the last 5 years were to be considered in any case, and for the period before that every state could select any continuous 5-year period that was particularly favorable to it.

However, countries that were still in process of building up their high seas fisheries requested opportunities to have higher shares. A percentage of the overall catch limit was set aside for these and for other special cases. Finally, some coastal states claimed preferences in the form of a special limit, the amount of which was long argued over. As a result, several schemes were evolved to meet the different interests, i.e. the 40-40-10-10 formula, which means: 40% of the overall catch to be allotted in proportion to catches over the last 3 years; 40% in proportion to catches over the last 10 years; 10% preference for coastal states; and 10% for special needs.

To protect the interest of coastal states when a considerable reduction of total catch becomes necessary, the so-called "sliding scale" was proposed, which provides that shares of coastal states shall not be reduced at the same rate as, but to a lesser degree than, the shares of other states.

The persistent decline of yields in major North Atlantic fisheries soon drove the commissions to action. First, amendments to the Conventions required for catch limit regulation were implemented. In 1969 ICNAF imposed the first overall catch limit in the North Atlantic — for the haddock fishery in subareas 5 and 4X. After the protocol to the Northwest Atlantic Fisheries Convention came into force, authorizing apportionment of catch limits to individual contracting states, the first multilateral catch limit regulations were imposed for the herring fishery in a special meeting of ICNAF in February 1972. This was followed, in the annual ICNAF meeting of 1972 in Washington, by imposition of catch limit regulations for almost every other major fishery in the Northwest Atlantic.

So far NEAFC has passed no catch limit regulations, because the requisite amendment to the Convention had not come into force for all contracting states by the last annual meeting. The Commission's decision to amend the Convention pursuant to Article 7, paragraph 2, had already been taken in 1970 (Resolution of the Commission on the Activation of Article 7, paragraph 2, of the Convention). As discussions in NEAFC on measures to restrict fishing intensity were progressing sluggishly, the Soviet Minister of Fisheries invited the Commission to Moscow for a special meeting on the ministerial level in December 1971. In this meeting the ministers strengthened their resolve to take action to restrict fishing intensity. Concrete decisions might have been taken in this conference if the Commission had had more time to prepare them.

PRACTICAL EXAMPLES OF MEASURES SO FAR CONSIDERED OR TAKEN TO RESTRICT FISHING INTENSITY IN THE NORTH ATLANTIC

Northeast Atlantic — The fishery in the Northeast Arctic area — A restriction of fishery intensity in this area was particularly urgent and was therefore always in the foreground of deliberations in NEAFC. Intensive fishing makes the size of catches increasingly dependent on numbers of the recruited year-classes (Fig. 3). As good year-classes were prematurely fished out by the fishing fleets in operations designed to seek them out, yields immediately plummeted when succeeding year-classes were not as good. The fleets then turned to other areas, where they caused similar developments. So it was that the Northeast Arctic area became a classic example of the effects of the so-called "pulse fishery." Although relatively few contracting states were involved in this fishery, agreement on concrete measures to reduce the fishing effort was hard to achieve because importance of these questions was so basic that many member states (which had no direct interest in the Northeast Arctic area) participated in the discussions. This was why the three countries with the largest shares in this fishery — Great Britain, the Soviet Union, and Norway — attempted among themselves and outside the Commission to come to an understanding on catch limits. These countries were prepared to apply separate catch limit regulations so long as the catches of third countries in this area did not exceed a certain quantity. Unfortunately, these efforts outside the Commission came to nothing. A temporary improvement of fishing, supported by two good year-classes, may have put off the decision, although imposition of catch limits could have made it possible to fish these good year-classes for a longer time, and have given the strengthened spawning stocks a better chance to reproduce.

Atlanto-Scandian herring — There was still no legal basis for catch limit regulation by the Commission, few member states were participating in exploitation of this stock, and the fishing fleets had shifted largely to other species on collapse of this fishery; Norway, Iceland, and the Soviet Union therefore came to an agreement outside the Commission on a quantitative limitation of their catches.

Herring stocks in the North Sea — There was also no legal basis for catch limit regulation by the Commission, and in addition no agreement was possible on catch limitations outside the Commission because the participating countries were so many. Yet there was no argument about the need to limit fishing mortality rate, and after many committee discussions at the 1970 NEAFC meeting, agreement was reached on closed seasons (fishing for herring in the North Sea was prohibited during May, and from 20 August to the end of September), which theoretically reduced catches by about 20%. In this attempt to curtail fishing mortality through closed seasons the following problems arose:

Maintenance of the market supply, particularly for the processing industry. The difficulties anticipated by many Commissioners did not become acute, partly because the industry had accumulated herring stores and partly because it was supplied with herring from fishing areas outside the North Sea (western British waters, Irish Sea, and Northwest Atlantic).

An attempt to restrict fishing for young herring for industrial purposes (fish meal and fish oil) was blocked by opposition of some member states which feared grave economic consequences for their cutter fleets, and which took the view that use made of catches could not be taken as a criterion for conservation measures. The demand that priority be given to the taking of herring for human consumption was discussed, but the Commission has not yet come to any decision because many delegations take the view that the Commission is not competent to establish such priorities.

The greatest difficulties were created by the demand for equal sacrifices. Closed seasons proved incapable of imposing even roughly similar restrictions on all participating countries. As nearly every combination of closed seasons gave rise to hardships, it was provided that member states could catch extra quantities for human consumption or for use as bait during a closed season. Extension of the closed seasons on herring in the North Sea recommended in December 1971 and May 1972 generated even greater hardships, and these extra quantities were increased. Although the Commission was not yet empowered to establish and apportion catch limits among the contracting states, in establishing these rules it did indirectly effect the first regulation of catch limits.

The Liaison Committee had supplied the Commission with excellent scientific material to assist it in its decisions on the regulation of the herring fishery. There were summaries of the monthly catches of member states from which it was easy to see what the effects of the various closed seasons would be. A table gave the delegates a summary of the conservation effects of different degrees of fishery restriction for a whole series of combinations in which either juvenile or adult herring were favored, or both were protected to the same degree (Table 1).

Indications are that the fleets affected by the herring closed seasons have been able to shift without major difficulty to other fisheries, and that they have not created major problems there. One reason may have been that they consisted mainly of smaller, more adaptable vessels that could readily find favorable alternative fishing opportunities (cod, haddock, mackerel, and whiting).

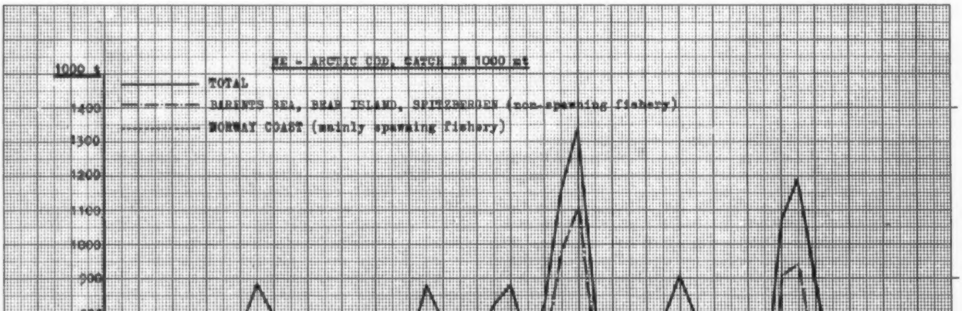

FIG. 3. Nominal catches of cod in arctic waters of Europe, in thousands of metric tons.

TABLE 1. Initial catch levels (1972) and percentage increase in catch and biomass from 1972 to 1975, for rates of fishing (F) of various combinations of juvenile and adult herring. (Juveniles are fish with one ring on the scale; adults are those with two or more rings) *Upper figure*: 1972 catch in thousands of metric tons: *Middle figure*: Increase in catch, 1972-75, as percentage; *Lower figure*: Increase in biomass of the stock, 1972–75, as percentage.

Adult	Juvenile (*F*)							
(*F*)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7
0.0	0	27	51	73	93	111	127	142
	–	0	0	0	0	0	0	0
	392	359	329	302	277	255	235	217
0.1	79	105	130	152	172	190	206	221
	243	164	120	90	73	59	49	41
	300	272	247	224	203	184	167	152
0.2	150	177	201	223	243	261	277	292
	196	148	115	92	74	61	50	41
	231	208	186	166	149	133	118	105
0.3	215	242	266	288	308	326	342	357
	158	123	97	77	62	50	40	32
	180	159	141	124	109	95	82	71
0.4	273	300	324	346	366	384	401	416
	128	100	78	61	48	37	28	21
	141	123	107	92	79	67	56	46
0.5	327	353	378	400	419	438	453	469
	103	80	62	47	35	25	17	10
	110	95	80	68	56	45	36	27
0.6	375	406	426	448	468	486	502	517
	83	63	47	34	24	15	7	1
	87	73	60	49	38	29	21	13
0.7	419	445	470	492	511	529	546	561
	67	50	35	24	14	6	–1	–7
	68	56	44	34	25	16	9	2
0.8	458	485	509	531	551	569	586	600
	54	38	25	15	6	–2	–8	–14
	54	42	32	23	14	7	0	–7
0.9	494	521	545	567	587	605	622	636
	43	29	17	7	–1	–8	–14	–19
	42	31	22	13	6	–1	–8	–13
1.0	527	554	578	600	620	638	654	669
	34	21	10	1	–7	–14	–19	–24
	32	22	14	6	–1	–8	–13	–19
1.1	556	583	607	629	649	667	684	699
	26	14	4	–5	–12	–18	–23	–28
	24	15	7	0	–7	–13	–18	–23
1.2	583	610	634	656	676	694	711	725
	20	8	–1	–9	–16	–22	–27	–31
	17	9	2	–5	–11	–17	–22	–27
1.3	608	634	659	681	701	719	735	750
	14	3	–6	–13	–20	–25	–30	–34
	12	4	–3	–9	–15	–20	–25	–29
1.4	630	657	681	703	723	741	757	772
	10	–1	–9	–16	–23	–28	–33	–36
	7	0	–7	–13	–18	–23	–28	–32
1.5	650	677	701	723	743	761	777	792
	6	–4	–12	–19	–25	–30	–35	–39
	3	–4	–10	–16	–21	–26	–30	–34

NORTHWEST ATLANTIC

ICNAF first adopted catch limit regulations for Georges Bank haddock in 1969. This stock yielded highly stable average catches of about 50,000 tons per year between 1935 and 1963, but in 1965 and 1966 massive international fleets, attracted by a particularly good year-class, caught 155,000 and 127,000 tons, respectively. This intensive fishing and a series of poor recruit year-classes caused yields to plummet first to the earlier level, and then down to around 25,000 tons in 1969. As ICNAF was empowered to establish catch limits, in 1969 it adopted a limit of 12,000 tons for subarea 5. To protect haddock stocks over the neighboring Browns Bank, a catch limit of 18,000 tons was adopted at the same time for Division 4X of subarea 4. The member countries were required to report their haddock catches from these areas to the ICNAF Secretariat every 14 days and their incidental haddock catches in increments of 700 tons. When the overall catch limit was 80% exhausted the Secretariat notified the member states, which had to discontinue taking haddock in the areas concerned within 10 days.

The establishment of an overall catch limit without apportionment among the member states led to no difficulties, because after the sharp decline in yields from this fishery only the USA and Canada were still fishing haddock.

To foster the recovery of the haddock stock, two closed areas were established at the same time in subarea 5. The stock had been so depleted by destructive exploitation, however, that catch limits had to be reduced further and closed areas and seasons were extended during the following years. Catch limits today are only 6000 tons for subarea 5, 9000 tons for 4X, and 4000 tons for 4W. In 1970 ICNAF also established an overall catch limit for yellowtail flounder in subarea 5.

Herring fishery — The "discovery" of the rich herring stocks on the Georges Bank and collapse of the herring fishery in the North Sea led to a dramatic intensification of fishing in the Northwest Atlantic. Catches, which had fluctuated between 150,000 and 180,000 tons from 1955 to 1961, soared in 1962 to almost 350,000 tons, and to 425,000 tons in 1966. The fishery expanded into statistical area 6 in the south and in 1968 peaked at 952,000 tons. Since then catches have declined. Although the overall catch was 714,000 tons in 1971 because of the development of new herring fisheries off Newfoundland, there were clear signs of overfishing in the major areas, Georges Bank in particular. That population was estimated at about 5000 million fish in the good years 1965-67 but only 1500 million in 1971. Thus, immediately after implementation of the amendment to the Convention making possible apportionment of the overall catch among the states, in a special meeting in Rome in January 1972, ICNAF restricted the overall catch in the southern part of the Convention area to 245,000 tons and apportioned this among the states. This was the first multilateral regulation of catch limits in the North Atlantic. The Commission took a realistic view in adopting it; catch limit was not reduced to the level recommended by the scientists, but remained more than 50% above it because the Commission was not prepared to impose such a sharp reduction on countries that had obtained high catches for the first time in the previous year. Catches made in the preceding year were taken as the criterion for the apportionment to reduce directly the actual fishing pressure. The same percentage reduction was applied to all, no preferences were given to coastal states or for other special needs. To be sure, the coastal states in the ICNAF Convention area were favored under this regulation by the fact that the Commission's regulatory measures did not apply in their territorial waters. But a special resolution called on member states to implement conservation measures outside the Convention area as well — that is, in both their territorial waters and in areas of the high seas adjacent to the Convention area. Moreover, it is noteworthy that member states to which no individual catch limits could be assigned because they had had no significant catches during the reference period were assigned an overall quota. Even if this was only symbolic, these states were not entirely excluded from the fishery. Consideration was also given to catches of nonmembers fishing in the Convention area. As no quotas could be assigned to them, their catch was deducted from the quantity to be apportioned. This was done on the assumption that they would reduce their catches too; accordingly, the Commission invited the attention of these countries to the catch limit regulations as provided in Article XIII of the Convention. A size limit provision for herring was eventually added to the catch limit regulations for the protection of immature fish stocks.

Cod fisheries — The striking decline in cod catches since 1968 impelled the Commission in its annual meeting of 1972 to establish the following catch limits for particularly intensively fished stocks: 575,000 tons off Labrador and Newfoundland (divisions 2J, 3K, and 3L); 50,500 tons in the Saint Pierre Bank area (3 Ps); 100,500 tons in the Grand Bank area (3N, 3O); 60,500 tons in the eastern and central Nova Scotia Bank areas (4V and 4W); 10,000 tons in the Gulf of Maine (5Y); 35,000 tons in the Georges Bank area (5 Ze and 5 Zw).

In the 1972 meeting catch limit regulations were also adopted for the following species: American plaice — 60,000 tons for the Grand Banks (3L, 3N, 3 O); Yellowtail flounder — 50,000 tons for the Grand Banks (3L, 3N, 3 O), and 26,000 tons for the southern New England area (5); silver hake — 90,000 tons for the Georges Bank (5Y, 5 Ze), and 80,000 tons for the southern New England area (5 Zw); red hake — 40,000 tons for the southern New England area (5 Zw).

As a supplementary measure a conservation area was established in subarea 5 for red and silver hake in which no fishing might be done during April. For the cod, haddock, and flounder fisheries in subareas 4 and 5, the mesh size limit was raised to 130 mm, and a minimum size was established for sea scallops in 5 Z.

CONSIDERATIONS ON THE APPORTIONMENT OF CATCH LIMITS AMONG MEMBER STATES

Incidental catches were included in these catch limit regulations. As a result, member states that had not fished the regulated stocks in particular, but had taken these species only incidentally, were given special limits for such catches. Unlike the quota regulations for herring, here the formula 40-40-10-10 was chosen as a basis for allocation. Because in 1972 "special needs" were asserted only to a limited extent, most of the 10% provided under this head was divided equally among member states; some countries used their shares to barter for catch limits in other areas.

PROCEDURE FOR THE ENFORCEMENT OF CATCH LIMIT REGULATIONS

ICNAF has left the manner of utilizing national catch limits up to the member states. These can issue licences to their vessels or allow their fleets to fish until the catch limit is reached. When a member state has reached its catch limit it must notify the Secretary immediately. Where an overall catch limit has been established for several member states in a body, catches must be reported in specific increments. The member states are obligated to ensure that all fishing vessels keep daily records of their catches, with precise data on position, amount, date, type of gear, amount of effort, discards, and disposition of the catch.

States to which no special catch limits have been assigned but which may fish within the limits of an overall catch limit must report their catches in increments of 100 tons each. The Secretary then estimates the time when the catch limit will be reached and communicates this to the member states, which must discontinue their fishing operations in the area concerned within 10 days from receipt of that communication.

Evaluation of Measures to Regulate Fishing Intensity

Both commissions began their deliberations on ways to restrict fishing intensity at the same time — in 1966–67 — and largely conjointly. The occasion for this was the steady decline in yields in the Northwest Atlantic area and the development of the herring fishery in the North Sea, but scientists had pointed out as early as the mid 1950s that regulations that did no more than allow the fish to grow to an economically and biologically optimum size would not suffice for the conservation of the cod and haddock stocks, and that the mesh size regulations would have to be supplemented by restrictions on fishing effort. This was why such measures were provided in the Northeast Atlantic Convention of 1958, but because of the procedural limitation that any such measure had to be approved by all member states before it could be applied, delay was inevitable. The Northwest Atlantic Convention of 1949 did provide the authority to establish overall catch limits, but this too was shown in practice to be insufficient for useful regulation of fishing intensity, and the Convention had to be amended in respect of the Commission's powers.

These inadequacies can hardly be blamed on the member states, because they were breaking new ground in international law. Moreover, after years of steady expansion of the fishery, and with overall catch limits in the North Atlantic rising ever higher, a reevaluation had become necessary. But the idea of fishing effort regulation was bound to encounter opposition not only in countries whose economic policies were liberal and oriented toward competition, but also in countries that were in process of enlarging their high seas fisheries as part of their economic development and in the interest of supplying their populations with animal protein. Moreover, the scientists could then not yet supply adequate data for such far-reaching administrative decisions, and admitted as much. Finally, the fishing industry resisted regulation of fishing on the ground of inaccuracies of scientific assessments; moreover, they doubted the seriousness of the situation because the trawler fleets could offset the decline in Northeast Atlantic yields by opening new fishing grounds in the western part of the North Atlantic. Besides, a few good year-classes had made the fishery in the Northeast Arctic area attractive again, if only temporarily. It was not until the end of the 1960s when virtually every stock of conventional species in the North Atlantic had been fished to and beyond the limit of its capacity, and appreciable declines in yield had become noticeable, that the fishing industry was ready for effort restriction.

The last delays of the regulation of catch limits resulted from understandable disagreements over allocation of the permissible overall catch. At this point the disputes between countries that pushed for early restrictions and those that still held back became a test of the cohesiveness of the commissions, and therewith of the principle of international fishery management. The breakthrough to catch limit regulation finally came under the considerable political pressure of a few coastal states whose relatively static fisheries had been jeopardized by a persistence of high fishing intensity. It may be regrettable that this political pressure was needed, but this procedure was in keeping with the rules of international cooperation. When it is considered how many technical problems were to be solved and how widely the interests of the 20 states represented on the commissions for the North Atlantic diverged, it becomes clear how much of an effort of goodwill was made. Hence it may be confidently asserted that the commissions, and the principle underlying their operation, have proved their worth.

Outlook for Future Developments

When ICNAF has imposed catch regulations on the major fisheries for 1973, NEAFC may be counted on to adopt similar regulations for the Northeast Atlantic shortly thereafter, because otherwise there would be a shift of vessels to unregulated areas, with catastrophic consequences for their stocks. The first order of business will be to protect the cod and haddock stocks in the entire North Atlantic. In this connection the Joint ICES/ICNAF Working Group on Cod Stocks in the North Atlantic recently prepared a comprehensive study that contains material of value to member states in considering their decisions. Once a beginning has been made with assignment of catch limits, such limits will have to be considered by the entire North Atlantic, and areas and stocks brought under regulations which had not hitherto been considered necessary to impose catch limitations.

The application and enforcement of catch limit regulations will raise other problems. Some doubt will probably arise among fishermen of the different member states as to whether the catch limits are really being adhered to. Any fisherman can observe whether his foreign colleagues are using the right mesh sizes, but the quantities taken can be controlled only to a limited extent under the Scheme of Joint Enforcement through the inspection of fishing logbooks, for example. Hence, the commissions will look for methods for limitation of fishing intensity which lend themselves more easily to international supervision. This may be practicable only by controlling the effort on the basis of number of fishing vessels and duration of their activity in certain areas or fisheries. Despite the inaccuracies and uncertainty of such regulations, they would offer the advantage that everyone could satisfy himself about the actual extent of fishing effort restriction.

Restriction of fishing intensity in the major North Atlantic fisheries could put an end to the economically senseless race for catches, and the associated expansion of fishing fleets, and initiate a phase of consolidation. The economic advantages to the fleets are manifest and are acknowledged by many fishermen. The disposition of vessels could then be better arranged, and there are well-founded hopes that the proportion of yields to fishing effort will rise and result in more profitable fishing.

Establishing catch limits for the traditional North Atlantic fisheries will confront the member states with the question of what to do with surplus fishing capacities. A considerable part of these can be disposed of without difficulty by scrapping obsolete vessels and not replacing them, and other vessels can be shifted to less intensively fished areas. But there are also in the North Atlantic a few stocks of so-called unconventional species, such as capelin, blue whiting, argentines, grenadiers, and cuttlefish that have hitherto hardly been utilized. A shift to these species is no simple matter, however, because it involves development of new fishing and processing methods, and products entailing an expensive marketing effort.

As the living resources of the North Atlantic will be utilized to the limit of their potential within the foreseeable future, the demand to assign priority to the catching of fish for human consumption will gain ground.

One serious problem for the international management of fish stocks in the North Atlantic is posed by the tendency to extend the boundaries of national sovereignty for fishery purposes to sea areas that have long been objects of international fishing and regulation. Thus, since September 1, 1972 Iceland has claimed the exclusive exploitation of a 50-mile wide zone embracing a major North Atlantic fishing ground from which the international fishery (not including Iceland) has heretofore taken an average of about 350,000 tons per year. Such action may be in conflict with the concept of collective responsibility for high seas fisheries, as the basis of international cooperation in the commissions is the common interest of the member states in conservation and rational exploitation of fish stocks. The concept of international fishery management is at stake here. It is up to the commissions to prove through the measures they take in future that this concept is workable, ensures optimum exploitation of fish stocks, and affords a fair balancing of the interests of participating states. The biological characteristics of fish populations and the peculiarities of the sea as their habitat actually predestine the ocean fishery to international management.

In every measure taken toward fishery management in the North Atlantic, this area must be viewed more as a whole. As the same long-distance fishing fleets operate in the Northeast and Northwest Atlantic, every measure must be judged in terms of its effects over the whole North Atlantic. Hence, ICNAF and NEAFC must intensify their cooperation and coordinate their measures. The same holds for cooperation between ICNAF and ICES in the realm of scientific research. It should be possible to arrive at organizational conclusions in the near future, as these bodies are staffed largely by the same people.

Management of International Whaling and North Pacific Fur Seals: Implications for Fisheries Management[1]

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Chapman, D. G. 1973. Management of international whaling and North Pacific fur seals: implications for fisheries management. J. Fish. Res. Board Can. 30: 2419–2426.

After many early vicissitudes, since 1911, the North Pacific fur seal stocks have been managed in the light of the best current information. During this time management problems have gradually changed from those of restoring depleted herds to those of finding the best exploitation strategy for herds at or near their maximum productivity (particularly in the case of the Pribilof and Robben herds). This has been achieved by agreement among the four nations who formerly captured fur seals either on land or at sea. The agreement includes a quota distribution of the kill.

Many stocks of the larger baleen whales have been decimated in various parts of the world, some during the last century but others since 1930 — particularly those of the antarctic. Although biological information was adequate to recognize this overexploitation and even to follow it quantitatively, the International Whaling Commission was powerless to halt the decline because its terms required unanimity of decisions and precluded assigning national quotas. Also, quotas were set for a combined take rather than by species. In 1972 these weaknesses were resolved, but not before blue and humpback whales were commercially extinct in the antarctic and fin whale stocks were far below the level of maximum yield. A recent forward-looking step by the Commission has been that of setting a conservative annual quota for the previously unused minke whales of the antarctic, this to be revised in the light of its reaction to exploitation.

Sperm whales have been only a secondary target for whalers during most of this century, while the polygamous habit and greater size of the male sperm whale have made their conservation easier than for the baleen species. However, the level of maximum sustained yield is now being approached and the strategy for attaining it is currently a lively topic of controversy and research.

Different parts of this history of seal and whale management can be applied in fishery management, either as guides for action or as horrible examples of the results of inaction. The principal difference is that fish stocks typically have a much larger replacement rate, hence can support larger rates of exploitation than the mammals can. However, this in no way decreases the need for rational management.

Après bien des vicissitudes initiales, l'aménagement des stocks d'otaries à fourrure du Pacifique Nord tient compte, depuis 1911, des meilleures données disponibles. Il s'agissait initialement de reconstituer les troupeaux appauvris, mais les problèmes d'aménagement se sont progressivement transformés en une recherche de la meilleure stratégie possible pour exploiter les stocks d'otaries à fourrure à leur niveau de productivité maximale ou au voisinage de celui-ci (notamment dans le cas des troupeaux de Pribilof et de Robben). Cet objectif a été atteint grâce à un accord intervenu entre les quatre nations qui chassaient autrefois l'otarie à fourrure, sur terre ou en mer, et qui prévoit un contingentement des animaux abattus.

Beaucoup des stocks de baleines à fanons ont été décimés dans diverses parties du monde, quelques-uns au cours du siècle dernier, mais d'autres depuis 1930 — en particulier ceux de l'Antarctique. On disposait bien de renseignements biologiques suffisants pour se rendre compte de cette surexploitation et même pour la suivre quantitativement, mais la Commission internationale de la baleine était sans pouvoirs pour mettre fin à cette extermination, car son règlement exigeait que les décisions soient prises à l'unanimité, et rendait impossible l'établissement de contingents nationaux. De plus, les contingents fixés concernaient les prises globales plutôt que les différentes espèces. En 1972, ces insuffisances ont été corrigées, mais les troupeaux de baleines bleues et de jubartes étaient déjà commercialement éteints dans l'Antarctique et les stocks de rorquals communs étaient très loin du niveau de rendement maximal. Pour préparer l'avenir, la Commission a récemment pris l'initiative de fixer un contingent annuel prudent pour les petits rorquals de l'Antarctique qui n'étaient pas exploités antérieurement, ce chiffre devant être revu compte tenu de la réaction du stock à l'exploitation.

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Pendant la plus grande partie de ce siècle, le cachalot n'a représenté qu'un objectif secondaire pour les baleiniers, mais, du fait des moeurs polygames et des dimensions plus importantes du cachalot mâle, la conservation de cette espèce a été plus facile que celle des baleines à fanons. Toutefois, on approche maintenant du niveau des prises maximales équilibrées et la stratégie à suivre pour l'atteindre est actuellement sujetté à de vives controverses et à des recherches actives.

Différents éléments de cet historique de l'exploitation des stocks d'otaries et de baleines sont applicables à l'aménagement des pêches, soit en tant que principes directeurs, soit en tant qu'horribles exemples des résultats de l'inaction. La principale différence est que, typiquement, les stocks de poissons ont un rythme de renouvellement beaucoup plus rapide et peuvent donc supporter des taux d'exploitation beaucoup plus élevés que les mammifères marins. Mais cela n'enlève rien à la nécessité d'un aménagement rationnel.

Después de muchas vicisitudes iniciales, desde 1911 las poblaciones de focas peleteras del Pacífico Norte han sido reglamentadas teniendo en cuenta la mejor información actual. Durante este tiempo han cambiado gradualmente los problemas de reglamentación, desde la restauración de los grupos agotados hasta los de encontrar el mejor sistema para explotarlas con un máximo de productividad (particularmente las de Pribilof y Robben). Ello se ha logrado mediante un acuerdo entre las cuatro naciones que antiguamente capturaban focas peleteras en tierra o en el mar. El acuerdo incluye una distribución de la producción mediante cupo.

En diversas partes del mundo se han exterminado muchas poblaciones de ballenas de barba de gran tamaño, algunas durante el último siglo y otras a partir de 1930 — especialmente las del Antártico. Aunque la información biológica era adecuada para reconocer esta superexplotación e incluso para estudiarla cuantitativamente, la Comisión Ballenera Internacional no tenía autoridad para hacer frente al problema, debido a que para actuar necesitaba unanimidad de decisiones, quedando excluida la asignación de cupos nacionales. Además los cupos se hicieron de manera combinada en vez de por especies. En 1972 se resolvieron estas deficiencias, pero ya se habían extinguido comercialmente las rorcuales y las ballenas jorobadas del Antártico y las poblaciones de ballenas de aleta estaban muy por debajo del rendimiento máximo. Con vistas al futuro la Comisión ha instituido recientemente un cupo anual muy bajo para conservar las ballenas pequeñas del Antártico, que habrá de revisarse teniendo en cuenta sus reacciones con respecto a la explotación.

Los cachalotes sólo han constituido un objetivo secundario de los balleneros durante la mayor parte de este siglo, mientras que las costumbres polígamas y el mayor tamaño de los machos ha hecho que su conservación sea más fácil que la de las ballenas de barba. No obstante, actualmente se está llegando al nivel del rendimiento máximo sostenido y la estrategia que se sigue para llegar a él constituye un tema de controversia y de investigación.

Distintas partes de esta historia de la reglamentación de las focas y de las ballenas pueden aplicarse a la pesca, bien como guía para tomar medidas, bien como un ejemplo horrible de los resultados de la inacción. La diferencia principal es que, las poblaciones de peces tienen tipicamente un índice de reemplazo mucho mayor y por ello pueden sufrir una explotación mayor que los mamíferos, pero ello no disminuye en absoluto la necesidad de una explotación racional.

Whaling Management Prior to the Second World War

COASTAL whaling is an old industry that may predate the time of Christ in some parts of the world — particularly off Norway and Japan. The sagas of two large "distant-water" whaling operations are well known — that in the North Atlantic for right whales and in the Pacific Ocean for sperm whales. The North Atlantic exploitation from the United Kingdom, Netherlands, and some other countries lasted for about 3 centuries. It collapsed with the near extermination of the Greenland right whale early in this century. The sperm whale industry that operated largely from New England ports had also declined to insignificant levels by the same time period, though all the evidence seems to point to economic reasons for this decline: increased costs, decreased oil prices in the form of competition from mineral oil, and alternate outlets for capital and labor in the rapidly expanding American agriculture and industry. During all these years, whaling was unregulated and management was purely in response to economic considerations.

During these centuries the rorqual whales — blue, fin, and the sei — were largely unexploited. This changed with the development of the explosive harpoon and more powerful ships. The greatest concentration of blue and fin whales were found feeding in the antarctic region in summer; exploitation of these stocks until the 1920's was largely land-based. The major change that opened all of the antarctic to exploitation was development of the factory ship, which is constructed to permit treatment of the whales on board and to be self-contained for periods of several months. The profitability of factory ships led to a rapid increase of British and Norwegian whaling fleets in the antarctic in the period 1925–30. The onset of the world-wide depression of the 1930's caused a collapse in the price of whale oil and a sharp reduction in effort and hence of catches in 1931–32. Thereafter, effort and catches increased again, even though the industry was concerned both about overproduction and possible overexploitation of the resource. This led to attempts to establish voluntary agreements to regulate and restrict catches. The agreements restricted the season of operations and set quotas by company in regard to production of oil and on number of animals to be killed. Later regulation restricted number of catches per factory ship.

These voluntary agreements were only partially successful because some companies in Norway and the United Kingdom refused to adhere. In addition, by 1937 German and Japanese companies had entered the antarctic whaling field.

In June 1937 the International Whaling Agreement was concluded. This agreement placed a ban on gray and right whales, and for other species restricted seasons and imposed minimum size limits. In 1938 the agreement was renewed with an added feature — a sanctuary area from 70°W long to 160°W long south of 40°S lat.

The International Whaling Agreement signed in London in 1937 by representatives of South Africa, the United States of America, Argentina, Australia, Germany, Great Britain, Ireland, New Zealand, and Norway is interesting for several reasons. It contains many provisions of an unusual nature in respect to regulation of an international resource. For example, it specified that each government must provide inspectors to enforce regulations plus information on all whaling operations under its jurisdiction and it must obtain from whaling operators a variety of statistical information to be communicated to the International Bureau of Whaling Statistics in Norway. It also regulated the manner of paying gunners and crews, to make it less likely that they would violate rules imposed by the agreement. There seems to be no record of how well the several governments enforced the rules on their whaling companies, but Japan did not sign the agreements of 1937 through 1939 and thus their nationals were not bound by these restrictions.

International Whaling Commission: Period of Inaction

The Second World War essentially eliminated pelagic operations in the Antarctic, though the South Georgia land stations (under British control) continued to operate. As the war came to an end the need for whale products was acute. This need appeared to play a large part in the thinking of the negotiators who came to London in January 1944 to plan for resumption of whaling operations. Some modifications were made to facilitiate increased catches, but at the same time it was recognized that there was a danger of overexploiting the stocks.

In the agreement signed at the end of this conference, a new management approach was introduced that was to have important consequences for the Antarctic stocks: a quota was fixed at 16,000 "blue whale units." A blue whale unit was defined to be 1 blue whale, or 2 fin whales or 2.5 humpback whales or 6 sei whales. The term blue whale unit calculated in this way had been used in the statistical analysis during the 1930s, but it now became an important management concept.

In 1946 a conference was convened in Washington to draw up a more permanent arrangement to manage the whale stocks and the industry. This, in effect, gave treaty status to the previous agreements. The treaty was ratified in November 1948. This treaty established a Commission that was empowered to amend the regulatory provisions that were carried over from previous agreements, was permitted to appoint a Secretary and staff, and to "organize studies and investigations relating to whaling."

While the Commission was empowered to develop a research staff and to conduct research, it chose not to do so. The main action of the Commission in its annual meetings was to review the regulations and make occasional modifications. During the 1950s the main concern was the quota. The catch of blue whales reached its high point in 1930–31 and thereafter declined. This decline continued despite the second world war respite, so that by 1953–54 the pelagic blue whale catch was only 2697. At the same time the fin whale catch increased, though in the late 1950s the increase was maintained only with increasing effort.

As a result the Commission took two actions: the blue whale open season was shortened and the quota (in blue whale units) was progressively reduced to 14,500 units. By the 1958 annual meeting there was controversy over the quota and over the failure of members to agree on some allocation of the quota. Such allocation had to be done outside the convention which specifically prohibited the Commission from "allocating specific to any factory ship or land station or to any group of factory ships or land stations." This meant that every factory had to compete with all others to get as large a share of the quota as possible: when achievement of the quota appeared to be imminent, a stopping date was established for all factories. Thus factory ships were encouraged to enlarge their fleets of catchers in this competition, even if this might cause excessive operating costs. As a result, Norway and the Netherlands withdrew from the Commission as of July 1959; to persuade them to reenter the quota was dropped for several seasons. At the same time, talks were initiated to provide for quota allocation and an International Observer Scheme to check on observance of the rules, and in particular on catches under the allocated quota. A quota allocation finally was agreed on in 1961 for three seasons: an allocation has been made ever since though the shares have changed greatly. The International Observer Scheme, which was agreed in principle at the same time, failed of implementation and eventually the Commission had to modify its schedule to revive it. In a modified form it was finally set in operation in 1972 and in the antarctic in the 1972–73 season.

International Whaling Commission: Responsible Action

Returning to the quota controversy, absence of any quota whatsoever disturbed those who believed that the whale stocks were in danger of being depleted, as had happened to the North Atlantic right whale and other local stocks. The sharp drop in blue and humpback whale catches made it clear that these species were, in fact, following the same path. The situation as to the fin whale stocks was less clear, so the Commission in 1960 agreed to appoint a special committee to assess the state of the whale stocks and to recommend levels of sustainable yield. This committee formed in early 1961, met with the Commission's Scientific Committee and outlined necessary steps including funding requirements. These were not approved until May 1962, at which time the necessary work was put in hand. The committee, in a preliminary report prepared in December 1962, made clear that fin whales were also being greatly overexploited and recommended a drastic reduction in the quota, as well as complete protection for blue and humpback whales. Almost complete protection for blue and humpback whales was adopted in 1963, but the reduced level of the quota remained a source of controversy. Though the quota remained far above the sustainable yield, the catch of fin whales dropped sharply. However, as their density decreased, the industry shifted to exploitation of sei whales that had hitherto been of little interest. Some other considerations also influenced this switch; an increasing emphasis on utilization of meat rather than oil made the sei whale relatively more valuable.

The continuing controversy in 1963 and 1964 threatened the continuance of the Commission; however, in May 1965 the parties to the convention called a special meeting at which agreement was reached to reduce the quota over three seasons, so that by 1967–68 the quota would be not greater than the combined sustainable yield.

This agreement was implemented and the quota reduced to the level recommended by the Scientific Committee.

During this period two complications arose with respect to the analysis: proper allocation of effort with varying emphasis on the two species of interest — fin and sei whales; also, during this period it became apparent that the method of ageing fin whales used in the late 1950s and early 1960s had been incorrect. Adjustment of the age data led to changes in the stock analysis. To resolve these questions, a special meeting of the Commission's Scientific Committee was held in Honolulu in early 1970. Complete agreement was not achieved, but differences were narrow and points of divergence clearly emphasized. This divergence of viewpoint as to level of sustainable yield of the fin whale stocks has made the Commission's setting of the quota more difficult though it has attempted to adhere to the agreement of 1965, not to exceed the level of the combined sustainable yields of fin and sei whales.

However, during this period several other management questions have arisen. Among several recommendations of the special study group (originally known as the Committee of Three) was one to the effect that the blue whale unit should be abolished in setting the quota. The special study group, and subsequently the Scientific Committee of the Commission, has emphasized that proper management calls for quotas by species and if possible by stocks. When the quota is set in blue whale units, the industry is free to pursue whichever species it wishes so that actual catches may depart widely from sustainable yield levels. In fact, this is what happened historically with the several species: blue whales were never in a position to sustain the high catches of the late 1920s and early 1930s, and were rapidly depleted when they were the preferred species.

As the catches in the antarctic declined, increased effort in the North Pacific led to larger catches there. The pattern in the North Pacific in many ways duplicated events in the southern hemisphere, except that stocks were initially smaller so that the time scale of depletion and action has been condensed. In the North Pacific, blue whales were depleted earliest and then fin whales became the primary target. By the late 1960s these were being overexploited and emphasis shifted to sei whales. Again, the pelagic whaling countries (now USSR and Japan) were reluctant to reduce quotas, but eventually adopted the procedure established by the Commission for the antarctic in 1965 — a gradual reduction to quotas at or below the level of sustainable yield. However, in the North Pacific there has been one difference: the quotas have always been set by species and not in blue whale units, though there has been some use of the blue whale unit for internal regulations and by industry. However, in 1971 the blue whale unit usage was completely eliminated in North Pacific management procedures and led the Commission to realize that this could also be done in the antarctic. This elimination was made at the 1972 annual meeting, and quotas were then set by species.

Sperm Whale Management

While the major American sperm whale operation dwindled to insignificance after the Civil War, small local sperm whale operations continued elsewhere. However, only after the second world war did sperm whaling become a major industry again. Japan and USSR began to catch large numbers in the North Pacific. Also, while factory ships operating in the antarctic were forbidden to take baleen whales north of 40°S this prohibition did not apply to sperm whales. Thus they turned to catching sperm whales during the voyages to and from the antarctic and occasionally south of 40°S also.

The biology of the sperm whale differs from that of baleen whales in several important respects that have a bearing on its exploitation and management. First, the sperm whale is polygamous: a large male holds a harem of 10–20 mature females together with some immature animals. Thus, any unexploited stock has a surplus of males that appear to be unnecessary for breeding purposes. Second, there is a marked sexual dimorphism — adult males may be as much as 20 ft (9 m) longer than adult females, and their oil yield is proportionately even greater. Finally, there is a great deal of segregation by sex and age: older and larger male sperm whales feed in high latitudes in the summer while females and younger animals remain in temperate and subtropical waters — roughly between 40°S and 50°N lat.

As there is a male breeding surplus in any unexploited stock, and as the larger, more valuable males are segregated by area, at least in summer, it is natural for the pelagic whaling companies to adjust their operations to exploit these animals first. This has happened particularly in the North Pacific but also to a considerable degree in the southern hemisphere. Note that this may not be the case with land stations, which have a limited radius of operation and have to take animals available within this radius.

Because of the emphasis on males and because of the size dimorphism, it was natural that the first regulations of consequence on sperm whales were size limits. The 1937 agreement specified that the lower limit for sperm whales should be 35 ft (15.9 m). This limit was continued in renewals of the Agreement and written into the schedule of the International Whaling Convention. It was later raised to 38 ft (17.2 m) for pelagic operations. As few females reach 38 ft, this size limit, if adhered to, would mean pelagic catches of females are negligible. There is some evidence that the limit has been occasionally flouted, but the proportion of females in pelagic catches has been in most seasons relatively small.

However, recent studies have shown that when the male surplus has been removed, the maximum sustainable yield will be obtained by reducing the number of females and thereafter taking an appropriate number of males and females.

Estimates have been given (IWC 1973) of the maximum sustainable yield and of the population level to attain this for southern and North Pacific populations. These are based on some unverified assumptions, because the actual response of sperm whale populations to significant female reduction has not been well documented. It is conjectured that the American industry may have taken a significant number of females in the Pacific Ocean in the 19th century, and recent operations off Chile and Peru have apparently reduced the female population to less than half its unexploited size. However, in neither case are there adequate biological observations needed as input for the population dynamics models referred to above.

There is agreement that the male surplus in the North Pacific Ocean has been essentially exploited and further sperm whaling should limit itself to the sustainable yield of both sexes. To this end, the Commission in 1972 adopted a quota by sex and removed size limits. Separate quotas by sex were also adopted for the southern hemisphere, though in some regions there still remains some male surplus.

Another type of management has been proposed for sperm whales: in 1965 the Commission passed a regulation banning sperm whaling between 40°N and 40°S. However, all pelagic whaling countries entered an exception to the regulation, as permitted under rules of the Convention. Thus the regulation was in effect null and void. Had it been operational, it would have certainly reduced the pelagic catch of female sperm whales, particularly in the southern hemisphere.

Northern Fur Seal

Fur seals throughout the world have, like whales, been subject to exploitation, but whereas whales have been sought for oil, meal, and meat, the fur seal has been of interest for its fur. Also, whereas whales must be taken at sea, fur seals are preferably harvested on their breeding islands, where they haul out on land. In the northern hemisphere, these have, in the past, been the Pribilof Islands off the Aleutian chain, the Commander Islands, which are the western extension of the chain, Robben (Tulyeni) Island, and several islands in the Kuril chain off Siberia. In addition, there is a small colony of a distinct species on Guadalupe Island off Mexico, and in the past decade the northern fur seal has begun to breed on St. Miguel Island of the Channel Islands off California.

While fur seals had been taken at sea along the rim of the Pacific Ocean earlier, intensive exploitation did not begin until their breeding islands were discovered late in the 18th century by Bering, a Danish explorer in the service of Russia.

The records of Russian exploitation of those animals is to be found in Kenyon et al. (1954). While at times it was rather heavy, there were other periods in which the stocks were allowed to rebuild so that on average it was a well-conducted operation. Like sperm whales, fur seals are polygamous and a male surplus is available for exploitation; and as males and females segregate on land, it is easy to exploit males alone. Apparently, under Russian control, males were the primary target.

However, with the acquisition of Alaska by the United States, there began 3 decades of excessive killing both on land and at sea. For a short period after the Alaska purchase, no control was exercised on the seal kill. Thereafter, a monopoly was granted to the Alaska Commercial Company. This company took slightly less than 2 million skins in the next 2 decades. At the same time pelagic operations were intensified by nationals of several countries, particularly Canada and Japan. The pelagic take in 1891–1900 was 421,000; in addition there were unreported losses at sea. This overexploitation threatened to decimate the resource and in 1891 a conference was held to take action. In particular, the United States wished to have pelagic sealing eliminated, but no agreement was reached. As the stocks continued to decrease, sealing both on land and at sea became less profitable. A second conference was held in 1909 and the resulting treaty signed in 1911 did lead to a ban on pelagic sealing. In return, the countries controlling the hauling areas of the seals agreed to contribute a portion of their harvest to the countries who were abandoning their rights to take seals at sea. In the case of the Pribilof Islands, the United States agreed to give 15% of the skins harvested to Canada and 15% to Japan. Similar agreements were made for the breeding areas in the western Pacific.

The Pribilof herd then numbered little more than 200,000 animals and it was deemed essential that it be given time to rebuild. However, in 1918 the harvest of males was resumed under government control and continued at an increasing level through the 1920s and early 1930s, but leveled off in the late 1930s. About this time Japan expressed dissatisfaction with the fur seal Convention. It claimed damage to fisheries by seals was excessive and in 1941 exercised its right to withdraw from the Convention with 1 year's notice.

The possibility of resumption of pelagic sealing was made moot by extension of the second world war into the Pacific theater. After the war, a new treaty conference was convened in Washington in late 1955. After prolonged negotiations, a treaty was agreed to in late 1956 that called for a 6-year period of research on fur seals to determine, among other things, the level of the herd that would provide maximum sustainable yield. The treaty also provided that the study should consider the relationship of fur seals to other living marine resources.

One of the questions discussed at the conference was whether the number of females was too large for the well-being of the herd. Up to that point, the harvest had consisted entirely of males, except for a few score females killed unintentionally each year. In 1956 there was a massive mortality of young seals in their first 6 weeks of life — over 100,000 on the two Pribilof islands. This seemed to confirm this impression, and it was determined to reduce the size of the female herd. This was done over the period 1956–63 though few females were taken in 1960. At this point, a new operational plan was put into effect; the harvest each season should include enough females to maintain the female population, without increase or decrease. This policy continued until 1969. Of course, it is to be realized that the potential increase had to be estimated, and hence there were fluctuations of the population around the desired level. Since 1969 there has been no killing of females except for research purposes, and the female herd is therefore increasing at its natural rate.

While this manipulation of the female herd has been in process, the normal harvest of young males has been taken. To the present, the recent male harvest has been on average below that of the 1940s and early 1950s, and in general below expectation based on population dynamics models of the fur seal herd. Several explanations are possible: the models have not taken into account the age structure of the herd and may be incomplete on this account; the herd may be affected by disturbance which is now greater than at any time since pelagic operations ceased; competition for food, due to large removals of flounders, Alaska pollock, and other species, by the large bottom fishery in the Bering Sea and elsewhere along the Pacific Coast of North America.

The latter possibility calls attention to the provision in Convention (originally for 6 years but since renewed) for research on the relationship of fur seals to other living marine resources. A pelagic program has been carried out on both sides of the Pacific since 1958, and much information has been obtained on fur seal habits and on their feeding areas in the Pacific by age and season. To date no attempt has been made to develop a model of their niche in the North Pacific ecosystem.

On the western side of the Pacific Ocean, after the 1911 cessation of pelagic sealing, the fur seal herds rebuilt much more slowly. After the second world war the herd on Robben Island came under Soviet control. Since the fur seal treaty was signed there has been a research program on the Commander and Robben islands similar to that on the Pribilof Islands. On all of these Asian islands there has been a harvest of young males throughout this period. There is strong evidence that the smaller Robben Island herd has reached a maximum level, perhaps limited by space.

The recent extension of the northern fur seal to one of the California channel islands has been noted. A similar extension has occurred in the Western Pacific — to islands of the Kuril chain. In this case it is a reoccupation of breeding areas that had been decimated by the harvesting operations of the 19th Century.

Comparative Management Programs

There is a strong analogy between whaling and high seas fisheries, while the fur seal resource is rather similar to anadromous fisheries in that they begin life within national boundaries, obtain most of their growth on the high seas, but return later to an area within national boundaries where they are harvested. It should be noted that fur seal harvesting costs on land are far less than that of pelagic operations, and land operations permit the easiest selection of animals by sex, size, etc. At the meetings of the North Pacific Fur Seal Convention Japan has stated that pelts are more valuable in their natural condition when taken at sea, and that a combined pelagic and land harvest might be optimum. As seals have always been taken at sea with shotguns, there is damage to the skins which lowers their value and tends to negate this proposition, as well as some loss of wounded animals.

The several types of regulation used for whaling management have also been used in fisheries — area closures, time closures, lower size limits, a total catch quota. The blue whale unit for management has been clearly demonstrated to be a failure. It is hoped that no similar management will be proposed for mixed fisheries. There are two important differences between whale exploitation and most fisheries: fluctuations in "year-class strength" are much less than in typical fish populations, and the ratios of sustainable yield to standing stock are much smaller in whales than in fishes. For example, the optimum fishing mortality coefficient for tuna is about 0.80, for halibut perhaps 0.30, while for whales it is only 0.04–0.06. However, absence of year-class fluctuations simplifies both management and exploitation of the resource. The low level of recruitment and hence of yield has an interesting and important effect at present for those stocks that have been overexploited. An overexploited stock is one that has been reduced below levels that would give the maximum sustainable yield. In these circumstances, prudent management would suggest that the catch should be reduced below the sustainable yield so as to rebuild the stock. Because in whale stocks the rate of rebuilding is of the order 4% per year, and the interest rate on risk capital is certainly more than 10% per annum, the present value of a whale spared for stock rebuilding is much less than of a whale killed now. Thus, without taking into account the increasing costs and the possibilities of additional competition in future years, from a purely economic point of view the Japanese industry is acting rationally to try to maximize the present catch of its factory ships and crews that are operational, rather than permit stocks to rebuild.

If the stock is to be rebuilt to maximum yield levels, other considerations must be brought to bear. This occurred at the 1972 meeting of the Commission when proposals were made to reduce the antarctic fin whale quota to zero. This proposal was defeated but the quota adopted is well below the presently estimated sustainable yield. What is the proper balance between economic interests of the present whaling industry and the world's need to rebuild the stock as rapidly as possible? The controversy is not yet resolved. One possible solution is to establish a phase-out period during which fin whale quotas are reduced to zero.

Management of fur seals also gives rise to a controversy similar to that occurring in both the North Pacific and North Atlantic with regard to salmon. One proposal that has been made for salmon is that they belong to the country which controls the river of origin. If adopted, this would eliminate all high seas fishing for salmon and deny any rights to high seas participants. The fur seal treaty (that of 1911) which banned pelagic sealing conceded that those previously engaged in the industry did have rights and therefore were entitled to a share of the continuing (land) harvest. This worked well from 1911 to

1941 but did not come to grips with some obvious problems. What right do potential pelagic fleets have? In the North Pacific, Korea, Taiwan, and China all have the potential to engage in pelagic fur seal operations. Are they entitled to a share of the harvest? In addition, fleets from other areas of the world could also enter the North Pacific to hunt for seals as they do in distant-water fisheries, and further complicate the question of property rights.

New Management Considerations

In the past 3 or 4 years, concern for the environment has brought forth new concepts, which may have profound effects on fisheries. As some marine mammals have, in the past, been exploited to the point of near extinction (blue and right whales, fur seals, and sea otters) or even complete extinction (the Steller sea-cow), there has been renewed anxiety by those concerned with the environment that this may be repeated with these or other species. In addition, there has been an increasing number of persons who oppose the killing of wild animals for any purpose, or for any purposes which are "nonessential." With a variety of positions, these are hard to distinguish; in fact, some (Small 1970) may suggest that substitutes can be found for whale products and at the same time suggest that whaling must be stopped to allow the stocks to rebuild to levels that can sustain higher yields so as to provide food for hungry mankind. While there are contradictory positions and while they are based on emotion rather than reason or scientific fact, those holding such views have become vocal in the United States and to a lesser degree in other Western countries. Such groups have persuaded the United States government to declare whales to be endangered species, and to lead the fight at the Stockholm Conference and at the meeting of the Whaling Commission in 1972 to establish a 10-year moratorium on whaling.

The 1972 meeting of the Commission also introduced one important new management concept and raised a second by implication. The Commission placed a quota on a species whose exploitation has barely begun, the minke whale in the antarctic. In 1971–72 the Japanese government licensed one factory ship to take 3000 minke whales. In 1972 the Commission set a quota on antarctic minke whales of 5000 animals. Hopefully, this quota is conservative and can be raised as further information is accumulated. This seems to be a sound principle for all fisheries management, whether by national governments or international agreements or agencies: establish a conservative quota at the outset and then expand the quota as information is accumulated that shows that the resource can withstand further harvesting on a sustained basis. This prevents an excessive capitalization of the resource that leads to overfishing, and possible collapse of the resource and of the industry. Of course the initial quota must not be so conservative as to stifle development of the resource entirely. For whales this is not serious, because the annual mortality rate is low and hence the resource remains available. In fishes, unexploited resources may be more quickly lost to natural mortality.

The principle of establishing conservative quotas at the outset of exploitation raises another question: on whom rests the responsibility of acquiring the information to adjust the quota to a more rational level. Further, as the information is acquired on whom does the burden of proof rest? In the past it has usually been the case that the regulatory body had to "prove" that the resource was being overexploited before restrictive regulations could be imposed. Thus in the late 1950s the blue whale stock was clearly declining drastically and yet, because no one could prove this unequivocably, the Commission postponed any serious restriction of blue whale catches.

At the Whaling Commission meeting in 1972, questions were raised as to adequacy of the scientific data base to estimate present sustainable yields, and there is no question but that there are some gaps in the data base.

Let us return to the first question: who collects the data? In the whaling industry there has been cooperation between the industry and government agencies. The latter have provided scientists who have been assigned to factory ships, etc. to obtain biological data. In addition, the whaling companies have done most of the postwar whale marking (the prewar schemes were carried out by the British government's *Discovery* expeditions). Further, the Japanese whaling companies have supported the Whales Research Institute which carries out studies on the high seas and in its own laboratories. The Norwegian whaling companies provided the original support for the Bureau of International Whaling Statistics, including the publications resulting therefrom. Such support of research and data collection by the fishing industry is rather less common, though one example is the Fisheries Research Institute of the University of Washington, which does receive support for research from the Alaska salmon industry. In general, fishing operations have been too small or too competitive to finance any substantial research that is useful for fisheries management.

Where the resource and therefore its exploitation is entirely national, it is appropriate for the national government to finance needed research by whatever manner it chooses. Where the resource is international, it seems appropriate that a large share of the basic data collection and the biological research necessary for managment should come from the exploiting industry. It would seem appropriate that those fishing for tuna on the high seas should be required to conduct tagging experiments in proportion to their level of exploitation. While the whaling industry has not provided whale marking in proportion to their catches nor has the level of marking been sufficient for the needs, still it has been well ahead of the fishing industry in this respect.

Further, it seems that when regional bodies are established to manage international resources, they should be provided with the means of obtaining impartial scientific evaluation of the level of exploitation the resource could sustain. This could be from their own staff but could also be provided by other means, i.e. by FAO or by a neutral group of disinterested but qualified scientists. When the original "Committee of Three" was proposed in 1960 to review the status of antarctic baleen whales, it was specified that the scientists for the study group be chosen from countries not involved in antarctic whaling. Those chosen were K. R. Allen, D. G. Chapman, and S. J. Holt, joined later by J. A. Gulland. More recently FAO has assembled a group to provide assistance to the Peruvian government in assessing the status, etc. of their great anchoveta stocks. In addition to Peruvian scientists, this group has consisted of the late M. B. Schaefer, the late G. J. Paulik, and L. K. Boerema, A. C. Burd, J. A. Gulland, G. I. Murphy, W. E. Ricker, and G. Saetersdal. As scientific management of all resources, fisheries and non-fisheries, national and international, becomes the rule rather than the exception, it is presumed that an adequate additional number of experts will be found or will be trained in order to provide such scientific expertise. From this worldwide corps, study groups can be recruited to reach fair and scientific decisions on proper levels of resource utilization. As pointed out earlier, if utilization starts from low quotas and works up, rather than from a situation where the "sky is the limit" until collapse is imminent, then pressures on rational managment will be much more tolerable. Further, if industry has an incentive to do research and provide data so as to enlarge quotas rather than the reverse, then the data base necessary for management could rapidly exceed that available up to the present. While neither the International Whaling Commission nor the North Pacific Fur Seal Commission has achieved these goals, they are closer than many other fishery bodies. Certainly we in the United States are far from achieving these management ideals in our national fishing or any other extractive industry. It is difficult to establish new rules in well-established industries, but perhaps such rules can be prescribed initially for exploitation of new resources both nationally and internationally.

COMMITTEE FOR WHALING STATISTICS [ed.] International whaling statistics. Vol. XVII (1947); and Vol. XVIII (1968) (Vol. XVII contains not only the whaling statistics from 1939/40 to 1944/45, but also the full text of the conferences in London in 1937, 1938, 1939, 1944, and 1945. Vol. XVIII contains the full text of the International agreement resulting from the 1946 conference in Washington, D.C.)

International Commission on Whaling. 1964. Report of the Committee of Three Scientists on the Special Scientific Investigation of the Antarctic Whale Stocks. Int. Comm. Whaling Rep. 14: 32–106.

1971. Report of the Special Meeting on Antarctic Fin Whale Stock Assessment, Honolulu, Hawaii, March 13–25, 1970. Int. Comm. Whaling Rep. 21: 34–39.

1973. Sperm Whale Assessment Meeting, Parksville, Vancouver Island, B.C., May 3–10. 1972. Int. Comm. Whaling Rep. 23: 55–58.

Kenyon, K. W., V. B. Scheffer, and D. G. Douglas. 1954. A population study of the Alaska fur-seal herd. U.S. Dep. Interior Spec. Sci. Rep. Wildlife No. 12.

For a brief discussion of actions of these two Commissions and the scientific information which has been presented as background to the actions, reference is made to the annual reports of the International Whaling Commission, issued at the Office of the Commission in London and the Proceedings of the Annual Meetings of the North Pacific Fur Seal Commission issued at the Headquarters of the Commission in Washington, D.C. In addition, the North Pacific Fur Seal Commission has issued Report on Investigations from 1958 to 1961, Report on Investigations from 1962 to 1963, Report on Investigations from 1964 to 1966.

Development of National Quotas by the International Commission for the Northwest Atlantic Fisheries[1]

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EDELMAN, M. S., AND I. I. DOKUCHAEV. 1973. Development of national quotas by the International Commission for the Northwest Atlantic Fisheries. J. Fish. Res. Board Can. 30: 2427–2435.

The Northwest Atlantic Ocean is one of the areas where fish stocks have been subjected to exceedingly high fishing pressure by many European and American countries, to the extent that some of them require strict control. International cooperation has been achieved through the International Commission for the Northwest Atlantic Fisheries (ICNAF). The Commission has applied conservation measures following scientific advice from various panels and committees, and stands as the first example of the application of national quotas for major exploited species.

By 1967, increases in total catches in the ICNAF Area were accompanied by decreases in the catch per unit of effort, and it became apparent that regulations on mesh size were not sufficient to maintain the stocks. The Standing Committee on Regulatory Measures was created to consider alternative regulations, and the economic and administrative problems connected with them. A Committee on Research and Statistics was charged with preparation of scientific data on status of the stocks and measures necessary to maintain and restore them.

As early as 1968, proposals were made to establish total catch quotas for principal species and to allocate these among the countries fishing. Adoption of this kind of regulation involved amendments to the Convention, and decisions were therefore difficult to achieve without a long and detailed study.

At the 1969 meeting, many stocks had declined further and stricter quotas were applied. The Commission recommended changes in the Convention to allow regulations to be made on economic and technical as well as on scientific data; this was the first step on the way to fixing national quotas. The Standing Committee on Regulatory Measures recommended overall quotas for the principal species and that these quotas be shared among participating nations, taking into account interests of states with developing fisheries, states whose fleets are incapable of being diverted to other fisheries, special interests of coastal states, and historical landings. The weight to be given to these various factors was left for further negotiations.

At the 1970 meeting, as only four member countries had ratified the agreements on national quotas, this problem remained unsolved. In 1971, despite further declines in catch and better research data, the Commission was still unable to agree on national quotas. But at an extraordinary meeting in January and February 1972, total quotas were established for herring in particular areas, and for national quotas. Thus for the first time in history national quotas were accepted by fishing countries. Later, overall and national quotas were recommended for the other principal species. It is hoped that this experience will be useful to other international bodies in resolving this complex problem.

L'océan Atlantique nord-ouest est l'une des zones où les stocks de poissons ont été soumis à une exploitation excessive par de nombreux pays européens et américains, de telle sorte qu'il a fallu imposer de stricts contrôles sur la pêche de certains stocks. Une coopération internationale s'est instituée par l'intermédiaire de la Commission internationale des pêches de l'Atlantique du nord-ouest (CIPAN). La Commission a appliqué des mesures de conservation faisant suite aux avis scientifiques fournis par divers groupes et comités de chercheurs; il s'agit là du premier exemple d'application de contingents nationaux pour les principales espèces exploitées.

En 1967, l'augmentation des captures totales dans la zone de la CIPAN s'était accompagnée d'une diminution des captures par unité d'effort, et il est devenu évident que les règlements relatifs au maillage ne

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

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suffisaient pas à maintenir les stocks au niveau voulu. La Commission a crée un Comité permanent sur les mesures de réglementation chargé d'examiner la possibilité d'adopter d'autres réglements et les problémes économiques et administratifs que cela poserait. Un Comité de la recherche et des statistiques a eu pour tâche de préparer des données scientifiques sur l'état des stocks et d'élaborer les mesures nécessaires pour assurer leur conservation et leur restauration.

Dès 1968, on a formulé des propositions pour établir des contingents globaux de capture visant les principales espèces et pour les répartir entre les nations halieutiques. L'adoption de ce type de réglementation supposait que l'on apporte des amendements à la Convention, et il était donc difficile de parvenir à des décisions sans faire une étude longue et detaillée.

Lorsque la Commission se réunit en 1969, de nombreux stocks avaient à nouveau diminué, et l'on fixa des contingents plus stricts. La Commission recommanda d'amender la Convention pour qu'il soit possible d'adopter des règlements fondés sur des données économiques et techniques, aussi bien que sur des données scientifiques. Ce fut la première étape sur la voie qui devrait mener à l'établissement de contingents nationaux. Le Comité permanent sur les mesures de réglementation recommanda des contingents globaux pour les principales espèces, contingents à répartir entre les nations participantes, compte tenu des intérêts des états dont les pêcheries sont en voie de développement, de ceux des états dont les flottilles ne peuvent être détournées vers d'autres pêcheries, des intérêts spéciaux des états riverains et des mises à terre effectuées dans le passé. De nouvelles négociations devaient permettre de pondérer les divers facteurs.

A la réunion de 1970, le problème ne fut pas résolu, puisque quatre seulement des états membres ont ratifié les accords relatifs aux contingents nationaux. En 1971, malgré une nouvelle diminution des captures et l'amélioration des données grâce à la recherche, la Commission resta incapable d'aboutir à un accord sur des contingents nationaux. Toutefois, lors d'une réunion extraordinaire, en janvier et février 1972, des contingents globaux et des contingents nationaux furent établis pour le hareng dans certaines zones. C'était la première fois que des nations halieutiques acceptaient la fixation de contingents nationaux. Par la suite, la Commission recommanda l'établissement de contingents tant globaux que nationaux pour d'autres espèces principales. L'on espère que cette expérience aidera d'autres organismes internationaux à résoudre ce problème complexe.

El noroeste del Atlántico es una de las zonas en las que las poblaciones de peces han estado expuestas a una actividad pesquera excesiva por parte de muchos países europeos y americanos, hasta el punto de que es preciso controlar rigidamente la explotación de algunas de ellas. Se ha logrado establecer una cooperación internacional en esta zona por medio de la Comisión Internacional de Pesca para el Noroeste del Atlántico (CIPNA). La Comisión ha aplicado medidas de conservación, valiéndose del asesoramiento científico de varios cuadros de expertos y comités, y ha sido la primera en introducir el sistema de cupos nacionales para las principales especies explotadas.

Para 1967, los aumentos de las capturas totales en la zona de la CIPNA iban acompañados por una disminución de la captura por unidad de esfuerzo, y era evidente que la reglamentación de la abertura de las mallas no era suficiente para conservar las poblaciones. Se creó un Comité Permanente sobre Medidas Reguladoras para examinar otras posibles soluciones y los problemas económicos y administrativos con ellas vinculados. Se creó igualmente un Comité de Investigación y Estadística, encargado de reunir datos científicos sobre la situación de las poblaciones y de preparar las medidas necesarias para conservarlas y restaurarlas.

Ya en 1968 se propuso introducir cupos totales de captura de las principales especies, distribuyéndolos entre los países que las explotaban. La adopción de una reglamentación de este tipo implicaba una enmienda del Convenio y, por tanto, era difícil llegar a una decisión sin un estudio largo y detallado de la cuestión.

Cuando se celebró la reunión de 1969, muchas de las poblaciones habían disminuido más aún por lo que se aplicaron cupos más estrictos. La Comisión recomendó introducir cambios en el Convenio de manera que fuera posible regular las actividades pesqueras basándose en datos económicos y técnicos, asi como científicos. Fue éste el primer paso hacia el establecimiento de cupos nacionales. El Comité Permanente sobre Medidas Reguladoras recomendó que se establecieran cupos globales para las principales especies y aconsejó que se repartieran estos cupos entre los países participantes, teniendo en cuenta los intereses de los estados con pesquerías en desarrollo, los estados cuyas flotas no pudieran orientarse hacia otras pesquerías, los intereses especiales de los estados ribereños, y los desembarcaderos tradicionales. El peso que había de darse a estos diversos factores se determinaría en negociaciones futuras.

En la reunión de 1970, dado que sólo cuatro estados miembros habían ratificado los acuerdos sobre cupos nacionales, el problema permanecía sin resolver. En 1971, a pesar de que seguían disminuyendo las capturas y se disponía de mejores datos de investigación, la Comisión no pudo llegar a un acuerdo sobre cupos nacionales. Pero, en una reunión extraordinaria celebrada en enero y febrero de 1972, se establecieron cupos totales para el arenque en algunas zonas, y se distribuyeron los cupos nacionales. Por primera vez en la historia, pues, algunos países pesqueros aceptaron la asignación de cupos nacionales. Más tarde, se recomendaron cupos globales y nacionales para las demás especies principales. Se espera que esta experiencia sea útil para otros organismos internacionales y les ayude a resolver este complejo problema.

THE rapid development of world fisheries in the past two decades along with introduction of highly effective fish detecting and fish catching gear, appearance in the world ocean of large fishing vessels capable of long cruising ranges and of catch processing in the area of capture, and entrance of a number of new countries into the world fisheries — all these have put many fish stocks under exceedingly high fishing pressure. The problem of keeping stocks at levels of maximum sustainable yield is now of vital importance. The situation has become acute for many stocks traditionally fished, but greatest concern has been felt for the status of stocks in certain important and long-standing centers of international fisheries.

One such area is the Northwest Atlantic Ocean, where many American and European countries carry on fisheries, and where some Asian countries also operate. Maintenance of fish stocks at the level which provides maximum sustainable yield in this area is, therefore, a problem that touches the national interests of many countries.

International cooperation in the rational conduct of fisheries in the Northwest Atlantic Ocean has been achieved through the International Commission for the Northwest Atlantic Fisheries (ICNAF). Being a highly complex international tool, the Commission has faced many serious problems during its history of over two decades. Whether there have been more failures than successes in its regulation of stocks is a debatable matter. But if the Commission is considered a success, this has been possible only because of the scientific approach, and because of the industry of those interested in elaborating more effective conservation measures despite the many compromises and hard decisions required in adopting these measures.

Fishing regulations in the Northwest Atlantic Ocean have advanced from the simplest, like mesh size limits, to much more complex measures, such as setting national quotas for various species. An analysis of the effectiveness of the conservation measures in the Northwest Atlantic Ocean will probably help in making decisions for many other areas of the world ocean.

Status of Stocks and Regulation of the Fisheries in 1968

In 1967 the overall catch of fish from the ICNAF area exceeded the previous year's level by nearly 150,000 metric tons (333,130 t compared to 318,900 in 1966; Tables 1 and 2). This increase in catch occurred because of a rise in the intensity of fishing, rather than through improvement of stocks; the important catch per unit of effort declined.

Discussions held as early as at the 17th meeting of ICNAF in 1967 revealed that regulation by mesh size limits is not sufficient to maintain stocks at the level which could provide maximum sustainable yields. The Standing Committee on Regulatory Measures was therefore established for the purpose of studying possibilities of more effective measures of regulation, such as total catch limits or a decrease in fishing pressure. The Committee was asked to consider conservation measures and the administrative and economic problems connected with them. Its first meeting was held in January 1968, where it was pointed out that more detailed information was needed on the status of fisheries in the ICNAF Area.

TABLE 1. Total catches by country in the ICNAF area, in thousands of metric tons.

Country	1967	1968	1969	1970
Canada (M)[a]	659	797	723	698
Canada (N)[b]	381	462	479	471
Denmark	124	97	78	64
France	159	176	113	73
Germany, Fed. Rep.	217	281	253	205
Iceland	3	1	13	–
Italy	–	–	–	–
Japan	–	5	12	19
Norway	59	74	54	47
Poland	120	187	160	171
Portugal	237	219	182	163
Romania	2	3	4	10
Spain	290	341	294	276
USSR	576	741	875	709
UK	80	47	6	7
USA	304	307	262	272
Non-member countries	141	182	1	–
Total catch	3352	3906	3528	3185

[a] M = Maritime Provinces and Quebec.

[b] N = Newfoundland.

TABLE 2. Catches of the principal commercial species in the ICNAF area, in thousands of metric tons.

	1967	1968	1969	1970
Cod	1685	1861	1438	1152
Haddock	117	97	72	48
Redfish	218	183	222	224
Halibut	13	17	2	2
Silver hake	103	85	135	218
Flounder	247	282	289	272
Herring	590	922	827	771

A view was expressed that despite the palpable benefits which the regulation of fishing intensity can bring about the increase of catch from the regulated stocks can turn out to be relatively small. Therefore the Committee on Regulatory Measures charged the Committee on Research and Statistics with preparation of scientific evidence on the status of the various stocks, to answer these questions:

Which stocks are agreed to be demonstrably fully exploited or overexploited? What sustainable yields could these stocks support, and what restrictions in effort are necessary to obtain those yields?

What are the total yields of demersal species which could be supported by the stocks in each subarea?

What stocks can be fished independently of other species of fish?

What additional information is required for the regulation of fishing intensity (a) through limitation of effort, and (b) through limitation of catch?

At the 18th meeting of ICNAF, the Committee on Research and Statistics could give answers only to some of the questions. However, the Committee could make a preliminary estimate of the extent to which the stock of each commercial species was being utilized, and it could reach conclusions regarding the size of the maximum possible yield for the next several years. On the basis of these findings the Stock Assessment Subcommittee came to the conclusion that by 1968 the catches of cod and rockfish in Subarea 1 had exceeded the level permissible for maintaining maximum sustainable yield. A similar situation was recorded in respect to haddock in Subarea 5, while catches of cod in Subareas 2 and 3, and silver hake and red hake in Subarea 5, had reached the maximum permissible size.

On the other hand, the Subcommittee on Stock Assessment noted that stocks of some commercial species were being underexploited. These included grenadier, halibut, capelin, argentine, mackerel, and herring. Later, as we know, the herring stocks declined.

The study of the status of stocks by the Subcommittee resulted in the recommendation to establish catch limits for cod in Subarea 1 and haddock in Subarea 5. As haddock in Subarea 5 is taken together with cod, a catch limit there for both species was recommended.

Both the Committee on Research and Statistics and the Subcommittee on Stock Assessment found it necessary to intensify research considerably to find the sizes of stocks of commercial species, fluctuations of these, and causes of population changes.

It was also noted that it would be much easier to limit the total catch than to decrease the fishing effort, because there is no standard international unit of fishing effort.

When the recommendations of the Committee on Research and of the Subcommittee on Stock Assessment were being discussed at the ICNAF meeting, the USSR made proposals to expand and accelerate joint coordinated research so that scientifically based data would be available by as early as 1970 to determine the maximum sustainable yield for the main species of fish. In addition it was suggested that ICNAF member countries should abstain from further increase of the catch from the main commercial species, and should not exceed the average catch for the past 3 years. The abstention was proposed to start in January 1969 and continue until the results of the studies mentioned would be available. The proposal made appropriate exceptions for the member countries which had recently started fishing in the ICNAF area, so that the interests of their developing fisheries were properly taken into account.

It was agreed in principle that there was need for expanding scientific investigations, but most delegations could not express the viewpoints of their governments with regard to abstention from a further increase of catches.

At this meeting the USA proposed principles for establishing general catch quotas by species and by fishing areas, and of allocating the quotas among countries. It was proposed to: establish global quotas only for species that are being demonstrably overfished (cod in Subarea 1; haddock on Georges Bank); adjust global quotas annually in accordance with scientific forecasts; allocate only 80% of the global quota or forecast sustainable catch as country quotas, leaving the remainder available to any member countries, or to countries with developing fisheries, or to third parties; allocate global quotas among countries participating in a fishery in proportion to their average catch during a 10-year period; when quotas are allocated, give coastal countries a special preference based on the following principles: (a) Account should be taken of the possible growth of the coastal country's harvesting capability, by providing for growth of the coastal country's quota as increased harvesting capacity can be demonstrated. Since 20% of the allowable catch is to remain unallocated, it is not necessary to place limitations on the increase. (b) If a reduction in the total allowable catch should become necessary, the quotas of both coastal and distant-water countries should be reduced, but because of the lack of mobility of the coastal fleets, the coastal country catch should be reduced less than that of the distant-water country.

The latter proposals were not fully discussed at the 18th Meeting due to insufficient time for studying them. It was decided that the Standing Committee on Regulatory Measures should consider these proposals at its next meeting, and that attention should be paid especially to principles and practical and administrative problems involved in development of regulatory schemes based on limitation of catch.

The United States memorandum circulated through the Secretariat of ICNAF in April 1968 was important to the negotiations for fixing national quotas. The proposals concerning amendments to Articles VII and VIII of the Convention, as contained in the memorandum, were motivated by the following: It was not feasible to apply measures of the type suggested by ICNAF scientists, i.e. catch or effort limitation, without some system of allocating the general quota among the member nations; It was the opinion of a substantial number of the members of the Committee that maximum economic benefits would not be achieved from regulation unless catch or effort quotas were allocated among the nations fishing the resource, and unless there were appropriate reductions in inputs at the national level; There was no dissent from the proposition that the Convention does not authorize measures for allocating quotas among the nations.

The authors of the memorandum used as a precedent the Northeast Atlantic Fisheries Convention concluded in 1959, which specifies various types of regulations that may be adopted, and suggested that Article VIII of the 1949 Convention should be amended as follows:

"I. The Commission may, on the recommendations of one or more Panels, and on the basis of scientific investigations, or economic and technical considerations, or both, transmit to the Depositary Government appropriate proposals, for joint action by the Contracting Governments, designed to achieve the rational utilization of the stocks of those species of fish which support international fisheries in the Convention area."

The following course of action was proposed to introduce expeditiously into the Convention the necessary flexibility in adopting regulatory measures:

That the proposed draft Protocol be adopted by the Commission at the 1968 Annual Meeting.

That the Commission request the Depositary Government to transmit the text of the Protocol to Contracting Governments and to open the Protocol for signature three months after such transmittal in the absence of objection by any Contracting Government.

In connection with this memorandum, it was agreed that improvement of the Convention to provide for better implementation of its objectives and tasks deserved approval in principle. A number of the provisions of the Convention obviously required amendments in accordance with the present situation. The delay in adoption by the Commission of the new proposals and changes of the Convention can be explained to a considerable extent by the fact that the mechanism of making changes, and their entry into force, was not clearly specified in the Convention. The existing mechanism was not efficient, and it was necessary to amend it in order to raise the effectiveness of the Convention itself, but the participants pointed out that the memorandum proposed changes of substance that needed thorough and detailed study. Some members believed that before adopting amendments to the Convention, the Commission could take measures to stablize the catches.

The proposals contained in the memorandum are to replace the list of concrete measures which may be adopted by the Commission (see a, b, c, d, e, of paragraph 1 of Article VIII of the Convention) by rather vague wording which would evoke serious difficulties, as it would result in practically unlimited extension of its functions. Further, Article VI of the Convention contains only one criterion for making recommendations to the Contracting Governments, this being the results of scientific investigations. It was impossible therefore to change paragraph 2, Article VIII, and paragraph 1, Article VIII, and at the same time to leave Article VI as it stood, as was proposed in the memorandum.

There was also some criticism with regard to the introduction of new criteria, i.e. "economic and technical considerations," as there is a possibility of interpreting these criteria in very different ways. Besides, the introduction of economic criteria would change the essence of the Convention, the purposes of which are to conduct investigations and to protect and conserve the fishery resources for maintenance of a maximum sustained catch.

As a result of the discussion the Commission recommended that the Contracting Governments consider the proposals carefully and inform the Commission of their views, so that at its 19th Meeting agreement might be reached on further action to be recommended to governments.

Status of Stocks and Regulation of the Fisheries in 1969

The total catch the year after the 19th Meeting of ICNAF increased by nearly 0.4 million tons to 3,711,651 tons. There was a considerable growth in catches of Canada, Poland, USSR, and Germany (Fed. Rep.), and decreases in catches of the United Kingdom, Denmark, and Portugal. Analyzed by species, the yearly changes revealed an increase in catches of cod and herring, and decreases in haddock, redfish and silver hake (Tables 1 and 2).

In its report at the 19th Meeting, the Committee on Research and Statistics noted that there had been a slight increase in the catch of demersal fish in 1968 compared to the previous year. The catches of bottomfish fell by 18% in Subarea 1, rose by 29% in Subarea 2, increased by 21% in Subarea 4, and remained at the same level in Subareas 3 and 5. The catch of herring in Subareas 3, 4 and 5 increased by 48% compared to the previous year, reaching 841,000 tons.

The Committee noted that the catch of cod in Subarea 1 had already exceeded the maximum allowable, as determined by the scientific committee. The Committee also noted that haddock stocks in Subarea 5 were in a very low condition: between 1935 and 1960 a stable haddock fishery yielded annually about 55,000 tons; in 1965 the catch in Subarea 5 increased and reached a maximum of 155,000 tons, falling to 44,000 tons in 1968. The Committee on Research and Statistics expressed the view that a general catch limit of 12,000–14,500 tons should be established for the next 4–5 years to preserve and gradually increase stocks of haddock. Besides, as conservation of haddock stocks in Subareas 4 and 5 would be effective only if imposed simultaneously, appropriate conservation measures should also be adopted for Subarea 4, the catch limit being 20,000–25,000 tons.

The report of the Committee on Research and Statistics and its recommendations were discussed comprehensively. It would be useful to describe briefly the results of the discussion of the draft protocol on amendments in paragraph 2 of Article VII and paragraph 1 of Article VIII of the Convention, because the further activity of the Commission in implementation of the Committee's recommendations was to some extent connected with adoption of proposals for enlarging the scope of the Commission's functions, to make it more flexible in determining the types of regulatory measures.

A draft Protocol was submitted to the 19th Meeting, with due regard to the 1968 discussion and to comments made by the delegations while discussing the United States memorandum. Briefly, the Protocol was that certain paragraphs of Articles VII and VIII be amended so that the Commission might, on the recommendations of one or more panels on the basis of scientific investigations, and on economic and technical considerations, work out proposals for joint action by the member countries designed to achieve optimum utilization of stocks which support international fisheries. This was the first step on the way to fixing national catch quotas. Whether these measures would be implemented was dependent on approval of the draft Protocol by the Contracting Governments, and their adoption of appropriate legislation.

The earlier proposal to abstain from increasing catches was regarded as being potentially highly effective, but as the Commission had already adopted a decision on catch limitation for those species in a state of greatest depression, stabilization of their catch on the present level would not give the expected results.

The principal recommendations of the report of the Standing Committee on Regulatory Measures were that, it is necessary to limit catches of some fish species to achieve maximum sustainable yield. This requires a total catch limit, with the total allowable catch shared among nations. It was proposed that the Commission should make a decision for each case, citing the names of species and areas to which the limitation is applicable. The objectives of such limitations might be: to maintain the stocks at or near the level producing the maximum sustainable yield; to restore them to this level if they are already overfished; and to stabilize stocks to prevent them from declining. To fulfil these objectives the Commission would have to determine the mortality rates of the stock in order to determine the level of limitation of the fishery. The total catch limit and determination of mortality rates could be made only on the basis of scientific evidence.

To allocate the global quota among countries, the majority of members agreed that a small proportion of the total allowable catch should be set aside and not included in the national quotas. This amount was to be used for new entrants and non-members. When allocating the remainder of the total allowable yield among national quotas, account should be taken of the interests of states with developing fisheries, states with fleets that could not be diverted to other fisheries, special interests of the coastal states, and historical performance of fishing states. National quotas should be flexible and capable of adjustment in the light of experience.

The Committee did not find it possible to determine the weight that should be given to these various factors in fixing national quotas. It was decided that this should be settled by future negotiations. But the basic principles in determining primary quotas, as viewed by the Committee, should be as follows. Historical performance should be measured by average catches over a datum period. Too long a datum period would obviously favor countries traditionally fishing throughout many years, whereas a short datum period would favor recent participants or countries which had undertaken to expand the scale of activity in recent years. The need to take into account the catches over several recent years was supported. Opinions were expressed that determination of quotas by averages over 10-year periods could give unjustified privileges to some states and discriminate against others, in particular the relatively recent entrants. A possible compromise might be to distribute half the quota on the basis of catches during a datum period of 10 years or longer, the other half on the basis of average catch during the last 3 years.

Some members suggested that about 80% of the total allowable yield should be alloted on a historic basis, leaving a balance of 20% to cover new entrants and non-members. The same part of the total allowable catch could then be used when the other factors mentioned above would be considered, i.e. the factors representing special interests of some member countries.

Other member countries of the Committee held the view that of the remaining 20% of the total catch, a proportion should be allocated equally among all member countries for further development of fisheries, instead of being restricted to countries with "special" claims.

The Committee considered that the permissible total catch would be reviewed annually, while the shares would be subject to review periodically.

The Committee recommended that if a country exceeded its quota, its share for the subsequent year should be reduced accordingly. Some countries held that such a reduction should be twice as great as the excess. It was proposed by some that in the event of underutilization of a national quota, it should be reduced and the excess shared among the other countries. Others suggested, however, that a reduction should apply only if a country failed to utilize its quota during several years.

The need was also emphasized to take into account the catches of non-member countries in making assessment of the total allowable catch.

The suggestion to give special rights in the open sea to the coastal states was criticized, because it would be in contradiction of the 1958 Geneva Convention. It was believed, however, that under certain conditions the interests of the small coastal fishermen should be taken into consideration. For example, if they entered the fishery recently their average catches for a number of years would be comparatively small and would not be considered properly solely under the "historical principle."

Negotiations on regulation of the haddock fishery in Subareas 4 and 5 were of particular importance. The status of haddock stocks was extremely poor, and investigations had clearly shown that regulation of the fishery by introduction of larger mesh sizes would not lead to restoration. A combination of quotas with the protection of spawning grounds would probably be most effective. The proposals to give preferential rights to coastal fishermen with vessels of less than 110 ft (33 m) were not supported and were withdrawn.

After long negotiations the Commission adopted recommendations for regulation of the haddock fishery in Subareas 4 and 5:

Global quotas for haddock in Subarea 4 and Subarea 5 to be established at 18,000 tons and 12,000 tons, respectively, for each of the years 1970, 1971 and 1972.

The competent authorities of every country fishing haddock should report bi-weekly landings from each subarea to the Executive Secretary. Information on haddock by catch taken by the vessels engaged in other fisheries should be reported in 700-ton increments. The Executive Secretary should notify each government of the date on which accumulative landings make up 80% of the global quota, after which all the governments should prohibit landings of haddock within 10 days.

Vessels engaged in other fisheries may have haddock on board in amounts not exceeding 10% by weight of all other fish on board.

Haddock fishery to be prohibited in March and April, i.e. during the period of spawning.

Status of Stocks and Regulation of the Fisheries in 1970

During the previous year the overall catch in the ICNAF area had decreased to some extent, caused by further deterioration of the stock condition and by a decreased intensity of fishing by some countries (Tables 1 and 2).

The Committee on Research and Statistics reached the following conclusions on status of stocks of the main commercial species.

The total catch of cod has reached the maximum allowable level, which should not exceed 1200 tons. If the intensity of fishery increases further a decline in catch can be expected.

Haddock stocks are still being overexploited. In 1969 the catch was the lowest in the history of the fishery. A further considerable decrease of fishing intensity is needed for conservation of these stocks.

Rapid growth of the herring fishery is observed, both on adult herring in the open sea and on young in bays. If continued this may adversely affect the status of herring stocks.

TABLE 3. Total catch limits and allocation of national quotas for 1973 according to recommendations of the 22nd Meeting of ICNAF (in metric tons).

	Cod						Yellowtail flounder		Silver hake			Red hake
	Subarea 2 Division 2; Subarea 3 Divisions 3K and 3	Subarea 3 Division 3P	Subarea 3, Divisions 30 and 3	Subarea 4, Divisions 4 and 4	Subarea 5, Division 5Y	Subarea 5, Divisions 5 and 5	Subarea 5 east of 69°	Subarea 5 west of 69°	Subarea 5, Division 5Y	Subarea 5, Division 5	Southern New England Stock	Southern New England Stock
Global quota	575,500	50,500	103,500	60,500	10,000	35,000	16,000	10,000	10,000	80,000	80,000	40,000
National quotas:												
Canada	71,064	9,200	12,700	18,400	100	4,000	–	–	–	–	–	–
Denmark	13,896	2,000	2,909	1,150	–	–	–	–	–	–	–	–
France	51,352	4,400	601	500	–	–	–	–	–	–	–	–
Germany (Fed. Rep.)	41,336	500	1,009	550	–	–	–	–	–	–	–	–
Iceland	6,224	500	909	450	–	–	–	–	–	–	–	–
Italy	6,056	500	909	450	–	–	–	–	–	–	–	–
Japan	6,000	500	909	450	–	–	–	–	–	–	–	–
Norway	17,480	2,500	3,309	450	–	400	–	–	–	–	–	–
Poland	40,944	500	1,109	550	–	–	–	–	–	–	–	–
Portugal	121,384	1,100	7,709	1,150	–	–	–	–	–	–	–	–
Romania	7,008	–	909	450	–	–	–	–	–	–	–	–
Spain	91,512	23,000	41,409	31,550	–	5,800	–	–	–	–	–	–
UK	19,708	1,900	2,009	450	–	–	–	–	–	–	–	–
USSR	81,536	3,900	27,100	2,900	–	2,900	–	400	–	55,000	47,000	22,000
USA	–	–	–	1,050	9,400	19,600	15,000	9,000	9,500	17,000	25,000	15,000
Other Contracting govts.	–	–	–	–	500	2,300	1,000	600	500	8,000	8,000	3,000

Excessive fishery for yellowtail flounder is observed, which undermines its stocks.

Some increase of the stocks of silver hake and red hake is in sight, but their abundance is still very low.

The need to continue the prohibition of the salmon fishery is recognized.

Acting in accordance with the above conclusions, the Committee recommended regulatory measures for each of the species mentioned, and the Commission based a number of decisions on the recommendations. However, by the 20th Meeting only the USA, the USSR, Spain, and Romania had ratified the Protocol on panel membership and on the regulatory measures approved at the 19th Meeting of ICNAF; consequently the Commission could not adopt any decisions about establishment of national quotas and restricted itself to discussing this problem.

Status of Stocks and Regulation of the Fisheries in 1971

In the period between the 20th and 21st Meetings of ICNAF the total catch in the Convention area continued to decline, and amounted to 3.16 million tons in 1970. The decrease from the previous year was 0.4 million tons (Tables 1 and 2). In its report at the 21st Meeting (1971) the Committee on Research and Statistics noted that part of the decrease might have resulted from a weaker fishing effort by a number of countries, and part from unfavorable natural conditions which had caused a fall in recruitment value. The major factor, however, was still excessive fishing, which in many cases produced landings in excess of the level of maximum sustainable yield.

Sufficiently precise data for stock assessment were available only for few species: cod in Subareas 1 and 2, haddock and yellowtail flounder in Subarea 5, and seals. The Committee emphasized that herring stocks had declined in every area, and that it was impossible to assess the level of maximum sustainable yield due to lack of recruitment data. After the second consideration of this problem, the Committee recommended a decrease in the 1972 catch of herring in statistical Divisions 5 and 6 to half of the 1969 catch, down to 108,000 tons. In Division 5Y, it was recommended to maintain the catch at the level of 1970 (40,000 tons), and in Division 4X reduce it to 80,000 tons, as compared with 130,000 tons in 1970.

The United States and the United Kingdom presented to the Standing Committee on Regulatory Measures a memorandum suggesting factors other than historical performance in determining national quotas. It was proposed to apply a "sliding scale" so that "special" interests of member countries are taken into account. Under this principle, which had been adopted by the Northeast Atlantic Fisheries Commission (NEAFC) in October 1969, shares of a coastal state would increase with the lower level of allowable catch.

The principle of "sliding scale" was criticized because it would automatically increase the share with the lower catch limit to a coastal state. This could have the result that fishermen of a coastal state would not be interested in the quickest restoration of the stock. The sliding scale principle was therefore dropped. The United States and Canadian delegations made a number of other proposals which provided for preferential rights of coastal states in determining national quotas. There was criticism of proposals to use computer-processed tables to establish national quotas. The tables clearly showed the great difficulties that would be met in trying to work out a uniform formula for allocation of quotas. In particular, it was indicated that the proportions of 20 and 80% could only be regarded as one of the possible approaches, as they ignore factors which would relate to a particular fishery. This approach could, for instance, make catches of coastal fishermen lower than the share allocated to them. Moreover, the proposed tables did not take into account the presence of vessels of non-member countries in a subarea, or the extent to which they are economically dependent on fisheries in a given division.

It was noted that if the Commission is given the right to allocate quotas that take into consideration economic and technical factors, the size of the national quota would have to be determined on the basis of an arrangement between countries concerned rather than on a purely mathematical basis.

There was a widely supported opinion that catches from years of overexploitation should be excluded when calculations were made of average catches over a number of years. Otherwise, countries which voluntarily leave a fishery for the sake of quicker restoration of the stocks (as was the case with the USSR with regard to haddock and yellowtail flounder) would be penalized by being given a smaller quota when stocks were restored.

Unfortunately, at the 21st Meeting, the Commission was unable to take any measures with respect to fixing national quotas for the main commercial species. But the discussions resulted in a considerable advance toward agreement on the principles for dividing the total allowable catch into national shares.

Extraordinary Meeting for the Establishment of National Catch Quotas

An Extraordinary ICNAF Meeting, held in January and February 1972, discussed the question of the status of stocks and regulatory measures for herring fisheries. In its report to the Commission the Committee on Research and Statistics had pointed out the serious condition of the herring stocks and recommended urgent conservation measures. The Meeting asked a Working Group for concrete proposals on conservation measures. The Working Group indicated that purely mathematical methods could not be used to determine universally acceptable quotas. Instead, direct negotiations were held among the delegations concerned, with due regard given to principles worked out by previous ICNAF meetings, i.e. historical performance, interests of new entrants, and some "special" interests of coastal states. It was also necessary to apply the principle of "equal sacrifice" to allocation of national quotas, so that the effects of new limitations should fall equally on all member countries.

As a result of difficult negotiations, the Extraordinary ICNAF Meeting established a 1972 global herring catch limit, and fixed national quotas:

Georges Bank

Total limit — 150,000 metric tons

Quotas (metric tons):	Canada	5,800
	Germany (Fed. Rep.)	31,600
	Japan	1,200
	Poland	49,400
	Romania	600
	USSR	48,200
	USA	4,000
	Other member countries	1,000

Catches of non-member countries not expected to exceed 8,200 metric tons.

Subarea 5 and Stat. Div. 5Y

Total limit — 30,000 metric tons

Quotas (metric tons):	Canda	6,000
	Germany (Fed. Rep.)	2,500
	USA	21,000
	Other member countries	250

Catches of non-member countries not expected to exceed 250 metric tons.

Subarea 4 and Stat. Div. 4X and (partially) 4

Total limit — 65,000 metric tons

Quotas (metric tons):	Canada	35,700
	Japan	1,000
	USSR	26,300
	Other member countries	1,000

Catches of non-member countries not expected to exceed 1000 metric tons.

At the same time, a recommendation was issued to establish a lower size limit for herring caught.

Thus, for the first time in the history of international fisheries, allocation of national quotas was applied as a measure aimed at conservation of the stocks. The Commission's recommendations were accepted by all the Contracting Governments soon after the Extraordinary Meeting. The prompt action demonstrated their deep concern about the problem of conservation, and willingness to promote international cooperation in this field.

At its 22nd Meeting the Commission went further in taking strict regulatory measures, and established national quotas for each of the principal commercial species, as is shown in Table 3.

Conclusion

The objective of this description of negotiations to fix national quotas within the framework of ICNAF is not to work out a theoretical basis for this complicated problem, but by using the example of a most respected international fisheries organization to illustrate how complex the questions involved may be, and how diverse may be the factors which help select the most rational solution. This summary also shows the possible ways of seeking compromise which would meet the interests of many states. It appears from the ICNAF experience that no general prescriptions can be made as to how to solve the problems of fixing national quotas.

It should be emphasized that the question of allocating national quotas is not unique to the ICNAF area. Similar problems have arisen in various degrees in the International Whaling Commission, the Northeast Atlantic Fisheries Commission, the Soviet-Japanese Fisheries Commission, and the North Pacific Fur Seal Commission. In each, these problems were different and were solved in their own way.

We can hope, when similarly serious situations have arisen in other international fishing areas, that in future negotiations, a scientific approach will be used to achieve the correct solution with due regard to the interests of the parties concerned, as has been done by ICNAF.

Fishery Regulations in the ICNAF Area[1]

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Several countries have been fishing in the Northwest Atlantic Ocean for 300 years, and recently pressure on the stocks has increased greatly. The need for conservation resulted in the creation of the International Commission for the Northwest Atlantic Fisheries (ICNAF) in 1950. By 1972 16 countries were party to the Convention.

When the Convention came into force, the catch in the Convention area was 1.7 million metric tons; by 1968 this had risen to 3.9 million metric tons, after which it has declined, largely because of lower cod, herring, and haddock catches.

The main objective of ICNAF is to maintain the fish stocks at levels permitting maximum sustainable yields. The first regulation applied by the Commission was the fixing of minimum sizes of trawlnet meshes used to catch a number of important demersal species. At its 1972 meeting other measures were introduced, notably the fixing of maximum quotas for several subareas and for the more important species. ICNAF is therefore the international commission which has the most thorough and extensive regulation measures.

At meetings in 1971 and 1972 the Commission concluded that exploitation of the major species in the ICNAF area was extremely high and that it was necessary to reduce fishing effort. These conclusions were arrived at on the basis of intensive research. Ten years of research on cod stocks is described as an example of this kind of work. It led to the conclusion that mesh size limitations were not sufficient to maintain the stocks of cod, and this was one of the strong reasons for adoption of the quotas, a step which is of great significance in international fisheries management.

Depuis 3 siècles plusieurs pays pêchent dans l'Atlantique du nord-ouest et récemment la pression sur les stocks s'est fort intensifiée. La nécessité de conserver les ressources a amené la création, en 1950, de la Commission internationale des pêches de l'Atlantique du nord-ouest (CIPAN). En 1972, 16 pays étaient parties à la Convention. Au moment où celle-ci entrait en vigueur, les captures dans la zone intéressée atteignaient 1,7 million de tonnes métriques; en 1968, elles s'élevaient à 3,9 millions de tonnes, après quoi elles ont fléchi, en raison surtout de la diminution des prises de morues, harengs et églefins.

La CIPAN a pour objectif principal de maintenir les stocks de poisson à des niveaux permettant des taux permanents maximums d'extraction. La première réglementation appliquée par la Commission consistait à fixer des tailles minimums aux mailles des chaluts utilisés pour capturer certaines importantes espèces démersales. A sa réunion de 1972, la Commission a adopté d'autres mesures et notamment fixé des contingents maximums pour plusieurs sous-régions et pour les plus importantes espèces. La CIPAN est donc la Commission internationale qui applique la réglementation la plus détaillée et la plus complète.

A ses réunions de 1971 et 1972, la Commission a constaté que l'exploitation des principales espèces dans la zone de son ressort était extrêmement intense et qu'il fallait réduire l'effort de pêche. Elle était arrivée à cette conclusion après des recherches très poussées. L'ouvrage mentionne à titre d'exemple 10 ans de recherches sur les stocks de morue. Ces travaux ont mené à la conclusion que les limites imposées à la taille des mailles ne suffisaient pas pour maintenir les stocks de morue et c'est l'un des arguments qui a fait adopter le système de contingents, mesure qui est d'une grande importance pour l'aménagement des pêcheries internationales.

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Son varios los países que pescan en el noroeste del Atlántico desde hace más de 300 años, y recientemente la presión a que están sometidas las poblaciones ha aumentado notablemente. La necesidad de adoptar medidas de conservación dio lugar, en 1950, a la creación de la Comisión Internacional de Pesca para el Noroeste del Atlántico (CIPNA). Para 1972, 16 países habían firmado el Convenio. Cuando este entró en vigor, la captura en su zona era de 1,7 millones de toneladas métricas; para 1968 había aumentado a 3,9 millones de toneladas métricas, y desde entonces ha disminuido, debido en buena parte a la reducción de las capturas de bacalao, arenque y eglefino.

El principal objetivo de la CIPNA es mantener las poblaciones ícticas a un nivel que permita obtener el rendimiento máximo sostenible. La primera medida reguladora aplicada por la Comisión fue establecer una abertura mínima de malla para las redes de arrastre utilizadas en la pesca de diversas especies demersales importantes. En la reunión de 1972 se aprobaron otras medidas, entre ellas el establecimiento de cupos máximos para varias subzonas y para las especies más importantes. La CIPNA es, pues, la Comisión Internacional que ha adoptado medidas reguladores más profundas y amplias. En las reuniones de 1971 y 1972, la Comisión llegó a la conclusión de que la explotación de las principales especies de su zona era excesiva y que era necesario reducir el esfuerzo de pesca. A esas conclusiones se llegó a partir de investigaciones intensivas. Como ejemplo de este tipo de trabajo se citan 10 años de investigaciones sobre poblaciones de bacalao. Se llegó así a la conclusión de que la limitación de la luz de las mallas no era suficiente para conservar las poblaciones de bacalao, y ésta fue una de las razones que motivaron la adopción del sistema de cupos, de gran importancia para la regulación de las pesquerías internacionales.

Stocks and Catches

THE Northwest Atlantic is one of the oldest fishing areas of the world, where several nations have been taking substantial catches for more than 300 years. During the last 20 years the catch in this area has been increasing rapidly; since 1966 it has been over 4 million metric tons annually, whereas in 1950 it was only 2.4 million tons. The 1970 landings were 4.2 million tons, which was about 7% of the total world catch of fish and other aquatic organisms.

The high biological productivity of this area, and the favorable conditions for the existence and reproduction of a number of major commercial fish species capable of reaching a high level of abundance (cod, haddock, silver hake, herring, certain flounders, redfish, and some others), for many years in the past ensured the sound state of the stocks and highly productive fisheries.

As in any other fishing area, fluctuations in abundance of various fish species had been observed which affected the size of the catch, but in the past, when fishing intensity was still low, these fluctuations in abundance and in the catch occurred almost exclusively as a result of variations in environmental conditions, and bore little relation to fishing. As a consequence there was no need to regulate the fisheries. However, the intensity of exploitation of commercial fish stocks in the Northwest Atlantic increased and approached the level where the necessity of regulating the fisheries became obvious. At the same time, an urgent need arose for a more comprehensive study of the biology and state of the stocks of commercially important fishes.

Establishment of ICNAF

With the above aims in view, the Convention for the Northwest Atlantic Fisheries was concluded. The Convention was signed in Washington on Feburary 8, 1949 and came into force on July 3, 1950 after it had been ratified by the United States, the United Kingdom, Iceland, and Canada. The purpose of the Convention was "... the investigation, protection and conservation of the fisheries of the Northwest Atlantic Ocean, in order to make possible the maintenance of a maximum sustained yield ..."

The area to which the Convention applies is shown in Fig. 1. For the purposes of the Convention the contracting governments established the International Commission for the Northwest Atlantic Fisheries (ICNAF). By 1972 the number of countries party to the Convention had increased to 16: Bulgaria, Canada, Denmark, Federal Republic of Germany, France, Iceland, Italy, Japan,

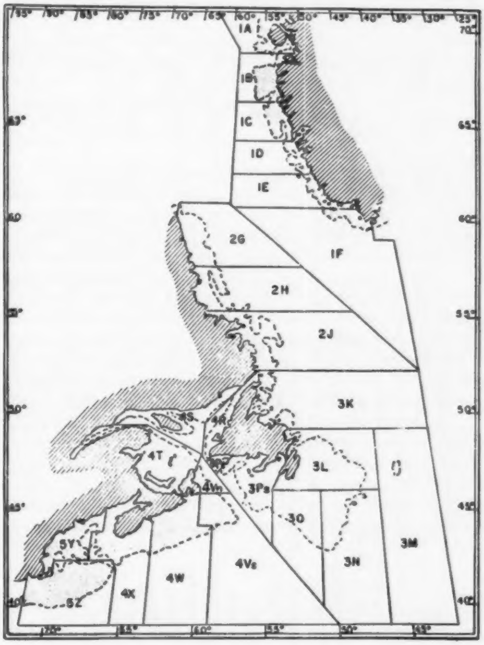

FIG. 1 Area applicable to the Convention for the Northwest Atlantic Fisheries.

TABLE 1. Catches in the ICNAF Area, 1954–71 (in thousands of metric tons).

	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Canada (M)[a]	357	364	400	410	400	417	429	396	465	504	535	555	638	659	797	723	698	680
Canada (N)[b]	325	294	314	289	234	290	294	259	279	297	292	306	336	381	462	479	471	416
Denmark	54	60	58	65	79	79	94	104	138	125	127	121	124	124	97	78	64	73
France	158	143	119	128	128	138	151	180	166	123	160	140	152	159	176	113	73	56
Germany, Fed. Rep.	2	22	37	27	71	85	97	174	197	200	149	181	178	217	281	253	205	134
Iceland	18	28	17	23	91	83	40	24	8	12	8	9	7	3	1	13	–	–
Italy	12	10	9	7	3	5	2	4	1	–	–	–	–	–	–	–	–	–
Japan	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	12	–	29
Norway	50	44	43	37	44	32	38	49	36	43	50	44	42	59	74	54	47	34
Poland	–	–	–	–	–	–	–	4	9	23	38	57	72	120	187	160	171	174
Portugal	196	206	225	205	179	160	185	197	218	231	210	197	202	237	219	182	163	153
Romania	–	–	–	–	–	–	–	–	–	–	–	3	3	2	3	4	10	8
Spain	140	161	149	146	123	143	177	208	206	225	230	234	241	290	341	234	276	265
USSR	–	–	17	69	117	182	258	341	370	491	617	853	710	576	741	875	709	902
UK	21	9	5	13	13	18	25	19	27	42	52	56	60	80	47	6	7	8
USA	513	504	541	560	515	501	477	441	482	465	388	350	329	304	307	262	272	226
Nonmembers	–	–	–	–	4	11	12	–	–	2	96	93	95	141	182	1	–	70
Total	1846	1845	1934	1979	2001	2144	2279	2400	2602	2783	2952	3199	3189	3352	3906	3528	3185	3228
Subarea 1	323	305	343	304	346	274	296	417	528	478	413	404	404	465	408	225	141	149
Subarea 2	22	26	35	32	119	114	280	297	266	223	251	377	366	329	482	441	239	246
Subarea 3	599	591	540	631	555	768	711	694	535	609	784	740	748	1103	1146	984	960	956
Subarea 4	451	462	511	491	522	524	549	498	578	753	740	777	882	723	963	1104	1158	1052
Subarea 5	414	428	470	514	489	459	443	489	693	714	756	890	867	732	907	873	687	815
Subarea unknown	37	33	35	7	–	5	–	5	2	6	8	11	2	–	–	–	–	–
Total	1846	1845	1934	1979	2001	2144	2279	2400	2602	2783	2952	3199	3189	3352	3906	3528	3185	3228
Cod	969	902	967	958	884	954	1134	1304	1340	1336	1402	1463	1477	1685	1861	1438	1152	1055
Haddock	162	198	194	171	138	129	159	179	138	126	142	249	203	117	97	72	48	49
Redfish	120	123	122	159	325	389	288	226	187	190	213	231	225	218	183	222	224	274
Halibut	4	4	5	6	6	6	7	6	5	4	5	5	5	13	17	2	2	3
Silver hake	41	46	40	57	49	53	47	43	95	270	302	373	172	103	85	135	218	224
Flounders	49	60	56	67	68	71	90	89	91	117	151	196	226	247	282	289	272	283
Other groundfish	151	166	160	161	161	160	120	116	101	167	138	210	215	152	172	166	111	214
Herring	152	149	152	172	184	154	180	179	344	285	302	263	425	590	922	827	771	693
Other pelagics	27	16	52	34	21	38	31	26	29	29	23	23	31	35	80	99	137	152
Miscellaneous	27	27	33	28	22	22	23	22	48	41	83	53	85	56	61	108	79	127
Other than fish	144	154	153	166	143	168	200	210	224	218	191	133	125	136	146	168	171	155
Total	1846	1845	1934	1979	2001	2144	2279	2400	2602	2783	2952	3199	3189	3352	3906	3528	3185	3228

[a] M=Maritimes and Quebec.

[b] N=Newfoundland.

TABLE 2. Total catch by all countries (in metric tons) in the West Greenland, Labrador, and Newfoundland areas.

Year	West Greenland			Labrador			Newfoundland		
	Total fish	including		Total fish	including		Total fish	including	
		cod	redfish		cod	redfish		cod	redfish
1953	223,048	205,423	13,465	109,114	108,767	6	431,011	323,747	45,596
1954	322,670	301,875	15,520	22,187	21,661	–	598,723	471,632	37,219
1955	304,629	265,318	32,249	26,217	25,841	–	591,312	429,040	17,603
1956	343,180	321,245	14,008	34,643	34,283	–	512,767	381,705	16,851
1957	304,073	269,035	28,137	32,456	32,146	–	630,724	448,815	57,664
1958	345,785	318,821	17,945	118,983	40,205	77,556	554,060	292,796	158,698
1959	273,978	233,542	32,540	114,000	59,994	52,772	767,425	425,261	246,108
1960	296,518	241,346	44,224	279,622	149,601	82,912	710,700	407,884	99,289
1961	416,979	345,391	54,418	296,658	264,985	25,594	694,123	460,646	89,920
1962	529,753	450,658	60,352	265,941	255,203	7,732	534,906	389,031	61,323
1963	477,675	405,771	46,657	223,454	215,709	6,134	608,820	466,422	68,664
1964	412,761	349,738	30,011	250,992	212,763	27,110	784,124	581,351	94,588
1965	404,166	360,341	19,052	377,159	332,775	23,497	740,170	496,059	111,890
1966	403,863	366,126	16,758	365,635	337,877	14,010	747,991	498,665	79,108
1967	465,169	429,479	13,210	328,448	297,809	17,050	1,103,018	720,604	89,057
1968	407,925	381,869	9,606	482,119	449,342	8,778	1,143,786	732,813	52,817
1969	225,130	204,750	4,552	441,411	412,293	6,098	982,705	569,087	87,032
1970	140,809	111,443	4,101	238,882	216,569	6,960	959,885	528,457	78,201

Norway, Poland, Portugal, Romania, Spain, the Union of Soviet Socialist Republics, the United Kingdom of Great Britain and Northern Ireland, and the United States of America.

At the time the Convention came into force in 1950 the catch in the Convention Area was 1.7 million metric tons. Increasing gradually, it reached a peak level of 3.9 million metric tons in 1968. The 1971 catch was 3.2 million metric tons. Table 1 shows the 1954–71 catches broken down by countries, ICNAF subareas, and major species.

As seen from Table 1 and 2 the total catch in the ICNAF area increased, up to 1968, mainly because of increasing catches of cod and herring. From 1968 to 1970 there was a considerable decrease in total catch, mostly as a result of lower cod catches, but also because of a drop in herring catches. Between 1967 and 1971 there was a significant decrease in haddock catches, after a remarkable increase in 1965–66, as compared with a stable level during 1954–64. There have been considerable fluctuations in catches of silver hake, production reaching its peak in 1963–65, followed by a decrease and then an increase during the last 2 years. The total catch of flounders increased during 1963–71, but not all species were involved. During the last 2 or 3 years there has been an increase in catch of mackerel.

TYPES OF REGULATIONS

As noted above, the main objective of the Convention is to maintain fish stocks at a level permitting the maximum sustained yield, through fisheries management based on scientific investigations conducted by the countries party to the Convention.

In accordance with Article XIII of the Convention the following measures can be applied to achieve this objective: establish open and closed seasons; close to fishing such areas as are found to be spawning areas or to be populated by small or immature fish; establish size limits for any species; prescribe fishing gear and appliances, the use of which is prohibited; prescribe an overall catch limit for any species of fish.

TRAWLNET REGULATIONS

The first regulation measure applied by the Commission was prohibition of the use of trawlnets having meshes of dimensions less than specified, to take fish of heavily exploited stocks of demersal species, where the catching of undersized fish was likely to affect adversely either the effective utilization of the stock or its reproduction.

Trawl regulations adopted by the Commission by 1973 in relation to bottom fisheries prohibited the use of trawlnets with codend meshes of dimensions less than 130 mm in manila twine netting, or the equivalent thereof when materials other than manila are used, to take the following species: cod, haddock, redfish, halibut, witch, American plaice and Greenland halibut in subareas 1 and 2; cod, haddock, redfish, halibut, witch, yellowtail flounder, American plaice, Greenland halibut, pollock, and white hake in subarea 3; cod, haddock, witch, yellowtail flounder, winter flounder, and American plaice in subarea 4[2]; cod, haddock and yellowtail flounder in subarea 5[3].

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[2] To become effective on January 1, 1974, except that the Commission shall determine at the 23rd annual meeting the effective date with respect to Div. 4X of subarea 4.

[3] To become effective on January 1, 1974.

The regulations prescribe the method of measuring mesh size and specify that trawlnets having a smaller mesh may be used in fishing for other species, provided that the incidental catch of regulated species is not in excess of a certain amount specified by the regulations.

CATCH QUOTAS

As the fisheries developed and the number of heavily exploited species increased, a need arose to introduce further conservation measures, and at its 22nd annual meeting in 1972 the Commission adopted the following measures in addition to mesh regulations:

Cod — Div. 2J and 3KL, quotas; subdiv. 3Ps, a quota; Div. 3NO, a quota; subdiv. 4Vs and Div. 4W, quotas; Div. 5Y, a quota; subdiv. 5Ze and 5Zw, quotas.

Haddock — Div. 4W, a quota; Div. 4X, a quota; subarea 5, a quota; subarea 5, an area closure.

American plaice — Div. 3LNO, a quota.

Yellowtail flounder — Div. 3LNO, a quota; Div. 5Z east of 69°, a quota; Div. 5Z west of 69°, a quota.

Red hake — Subdiv. 5Zw and statistical area 6, quotas.

Red and silver hake — Subarea 5, an area closure.

Silver hake — Div. 5Y, a quota; subdiv. 5Ze, a quota; subdiv. 5Zw and statistical area 6, quotas.

All demersal species — Part of Div. 5X area, closure during March, April, and May.

Scallop — Div. 5Z, a size limit.

Herring — Georges Bank, a quota; Div. 5Y, a quota; Div. 4X and part of div. 4W, quotas, subareas 4 and 5, size limitations.

Atlantic salmon — Convention Area catch limitation. Steps have been taken toward conservation of Atlantic salmon by prohibiting salmon fishing in the Convention Area outside national fishing limits, but agreement has not yet been reached.

SEALING REGULATIONS

Conservation of harp and hooded seals in the Convention Area is managed by a catch quota for harp seals, by fixing opening and closing dates of the sealing season, and by prohibiting the killing of mature seals on the breeding grounds.

Basis for Regulations

At present, ICNAF seems to apply the most extensive and varied regulatory measures of all international fishery bodies. None of these measures except mesh-size regulations in trawl fisheries for bottom species have been used long enough to produce any appreciable effect on the state of the fish stocks, and it is too early to appraise their effectiveness. Nevertheless, some experience has been gained in the process of working out these regulation measures as a result of extensive discussions of research and statistical data in various ICNAF committees, which makes it possible to present some considerations in relation to fishery regulation problems in the area.

The regulation measures are based on recommendations from ICNAF's Assessments Subcommittee and the Standing Committee on Research and Statistics (STACRES). At the 21st ICNAF annual meeting in May 1971, STACRES noted that the total catch in the Convention Area decreased by about 13% from 1969 to 1970, continuing the decline from the highest recorded catch in 1968. Decreases occurred in all major species — cod, haddock, redfish, flounders, and herring. The Committee decided that basically these decreases were a result of the extremely intensive fishery, and that the catch had exceeded the point of maximum sustained yield in many cases.

At the midterm meeting in January 1972 and at the 22nd annual meeting in May–June 1972, STACRES, on the basis of research and statistical data, again came to the conclusion that exploitation of major commercial species in the ICNAF area was extremely high and that it was necessary to reduce fishing effort in order to maintain stable fisheries. This conclusion was reached on the basis of investigations conducted by the research bodies of member countries, both independently and jointly according to coordinated programs.

To assess the state of fish stocks and the fishing intensity, the Assessments Subcommittee and STACRES apply the various methods currently used in fishery research. Juvenile abundance and the size of recruitment are taken into consideration. Statistical and biostatistical data, and age and size compositions of the stocks, are used to estimate fishing mortality. Of particular value for stock assessment purposes are quantitative surveys of young and adult fish, which in recent years have been increasingly used in fishery investigations. Of considerable importance for herring stock assessments were surveys over several years aimed at estimating spawning ground areas and the quantities of eggs laid.

Example of Establishing Regulations for Cod

Regular fishery and hydrographic studies are essential for assessing the current state of a stock and for forecasting its future condition, and consequently for deciding on management measures. An example is given below of an assessment of cod stocks in the ICNAF subareas 1, 2, and 3, where cod is the major commercial species (Table 2). The development of trawl fisheries in subarea 2 (Labrador) started a little more than 10 years ago. Investigations carried out by the Polar Research Institute of Marine Fisheries (USSR) showed that the major cod spawning takes place over the continental slope of Labrador, mainly in its northern part, whence the developing eggs and larvae are carried southward by the current. Young cod at the age of 3 years (4th year of life) stay on the shelf of the northern Newfoundland Bank (Div. 3K), and on reaching the age of 4 years they start their northward migration to the Labrador region.

Table 3 shows that the Labrador cod are characterized by relatively small fluctuations: the 3-year-olds of the strongest year-class are only five times as numerous as the 3-year-olds of the poorest year-class. (For cod of the Grand Bank of Newfoundland, West Greenland, and the Barents Sea this ratio is as high as 50:1 or more.) The relative stability of the annual recruitment of Labrador cod is determined by their spawning under the ice cover, by a low and practically constant runoff from the coast, and by the southward drift of eggs and larvae. Because of

Table 3. Mean catch of young cod (in numbers) per hour's trawling with a survey trawl.

Year-class	No. of 3-year-olds in Div. 3K	No. of 2-year-olds	
		Div. 3N	Div. 30
1959	21	–	–
1960	11	2	0
1961	20	4	3
1962	15	8	2
1963	36	5	1
1964	8	137	13
1965	15	14	12
1966	27	27	17
1967	32	3	4
1968	40	109	28
1969	–	11	6

these small fluctuations the state of the population is easily affected by heavy fishing, as no particularly strong year-class is likely to appear to compensate quickly for the fish removed. Table 4 shows that the mean age and weight of the Labrador cod in trawl catches have been decreasing gradually, and fish of older ages (over 10 years) occur less and less frequently in catches.

The magnitude of the annual recruitment to the stock has not decreased. Table 3 shows that at the end of the period considered the spawning stock was capable of producing just as strong a year-class as previously. Table 4 shows no downward trend in the mean number of fish caught per hour of trawling. Nevertheless, the total biomass of the commercial stock has been decreasing due to a reduction in average weight of fish. As the weight of an 8-year-old fish is 1.4 kg and that of a 7-year-old is 1.2 kg, the change in age composition (Table 4) means a reduction in the biomass of the commercial stock by about 15%. This decrease is likely to continue until there is a dynamic equilibrium between the mean annual recruitment and the removal by fishing. On the basis of the selective properties of currentlyused trawls, this equilibrium should be reached when the mean age of the cod caught is 6 years and the mean weight is about 0.95 kg. In this event the weight of the commercial stock will have decreased by about 30% as compared with catches at the beginning of intensive trawl fisheries.

It follows that a gradual restoration of the former mean weight and total biomass of the Labrador cod can be achieved by limiting removal by fishing. The decision to limit cod catches in the South Labrador area adopted by the 22nd annual ICNAF meeting is expected to have a favorable effect.

A further increase in mesh size without accompanying catch limitations would not, in our view, yield any results, because most cod (just as any other commercial fish) do not survive after escaping through codend meshes, and because when catches are large (as they often are in Labrador cod fisheries) even large-meshed trawls are likely to retain small fish along with big ones.

In subarea 3 (Newfoundland) there are several cod populations, of which the most important is the southern population occurring on the southeastern (Div. 3N) and

Table 4. Percentage age composition of cod in the South Labrador area in the first half of the year.

Age	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
3	–	0.6	0.2	–	–	–	–	0.2	0.2	4.4	–
4	5.5	1.9	3.6	1.1	5.8	8.5	2.3	2.1	3.0	6.5	12.0
5	6.4	15.2	4.7	7.9	5.8	34.7	15.4	21.0	14.7	16.4	15.0
6	19.3	22.4	11.7	13.5	12.1	21.3	25.5	20.5	30.1	18.2	25.0
7	21.2	15.5	32.8	32.6	16.3	16.1	17.6	19.6	22.0	15.9	20.8
8	11.7	31.2	16.6	27.7	23.4	8.8	17.0	16.4	15.1	16.2	12.7
9	12.5	6.9	8.3	6.6	20.4	3.3	8.7	8.9	6.8	9.2	8.1
10	9.4	6.2	7.1	2.7	7.4	4.2	5.2	4.2	3.2	5.7	3.8
11	2.9	4.8	3.4	2.8	2.9	0.4	5.0	3.1	0.9	2.9	0.9
12	3.7	2.4	3.5	2.0	1.7	2.0	0.9	2.9	1.9	1.9	0.7
13	2.9	3.1	1.9	1.1	2.0	0.7	0.6	0.4	1.4	0.9	0.7
14	1.7	1.2	1.5	0.6	1.0	–	0.7	0.4	0.2	0.8	0.2
15	1.6	1.5	1.1	0.6	0.4	–	0.1	0.3	0.3	0.6	0.1
16	0.9	1.3	1.2	0.2	0.8	–	0.5	–	0.2	0.4	–
17	0.2	2.2	0.8	0.3	–	–	0.4	–	–	–	–
18	–	0.9	0.4	0.1	–	–	0.1	–	–	–	–
19	–	0.4	0.8	0.2	–	–	–	–	–	–	–
20	–	0.1	0.2	–	–	–	–	–	–	–	–
21	–	0.2	–	–	–	–	–	–	–	–	–
22	–	–	0.2	–	–	–	–	–	–	–	–
Mean age	8.0	8.1	8.2	7.6	8.0	6.3	7.3	7.1	7.0	7.0	6.6
Mean weight, g	1534	1522	1394	1357	1346	1067	1036	1390	1422	1169	1086
Mean number per hour trawling	1874	1984	2733	2793	2541	2867	2326	2756	2205	2335	2136

TABLE 5. Summary of present state of ICNAF cod stocks and recommended catch quotas for 1973, in thousands of metric tons. NK = not known.

Stock	Long-term sustainable yield[a]	Fishing mortality		Catch 1971	Catch estimate[c]		Recommended quotas for 1973	Comments
		F*max*[b]	F1970		1973 F at F1970	1973 F at F*max*		
Subarea 1	300	0.6	0.6	120	102	102	102	1971–73 catches below the long-term sustainable yield owing to poor recruitment
Div. 2J–3K–L	600	0.4	(0.55)	450	825	654	650	Estimates of catch in 1973 the mean of a range of estimates. The fishing (and hence catch) is very sensitive to ice conditions
Div. 3N–O	(75)	(0.2)	NK	120	NK	120	70	F*max* for 1963–66 data; no recent information
Div. 3Ps	60	0.3	0.55	60	110	70	70	Prognosis for 1973 depends critically on the size of the 1968 year-class
Div. 4T–4Vn	NK	0.4	0.3	57	50	60	60	Projected catch in 1973 based on assuming that stock abundance remains at average level
Div. 4Vs–4W	60	0.45	0.4	53	60	60	60	Projected catch in 1973 based on assuming that stock abundance remains at average level
Div. 4X Offshore	NK	0.35	0.8	10	NK	NK	<5	Data not adequate to project 1973 catch, but recent poor recruitment indicates that fishing mortality should be reduced to lowest practical level
Div. 5Z	35	0.3	NK	27	28	NK	35	Data not adequate to project catch in 1973, but it is expected that 1971 level can be maintained
Div. 2G–H				12				No assessment
Div. 3M				19				No assessment
Div. 3Pn–4R–S				124				No assessment
Div. 5Y				7				No assessment

[a] Average recruitment × maximum yield-per-recruit.

[b] Fishing mortality giving maximum yield-per-recruit with the current age at first capture.

[c] Estimates of 1973 catches depend on projection of stock sizes in 1973. They are influenced by F in 1971 and 1972 (they are assumed here to remain at the 1970 level) and on the reliability of future recruitment. Accuracy is probably not better than ±25%.

southwestern (Div. 30) slopes of the Grand Bank. Cod have been fished on the Grand Bank since the 16th century and catches have increased almost continuously. About 60% of the total catch is taken with bottom trawls, about 20% by the Canadian inshore fishery, and the remainder by Portuguese dory vessels and Spanish pair trawlers.

Southern Newfoundland cod are characterized by sharp year-class fluctuations. Young fish of a strong year-class may be 50 times as abundant as those of a poor year-class (Table 3). Sharp fluctuations in year-class strength caused by the complex and variable environmental conditions on the southern Grand Bank (the close juxtaposition of warm and cold currents, vast shoals cooled in winter and warmed in summer) offset the effects of intense fishing, and the appearance of a strong year-class restores the abundance of the exploited stock. Because of this the determination of annual catch limits for the southern Newfoundland cod is much more difficult than for Labrador cod.

Variations in size and age composition of southern Newfoundland cod do not show any definite trends; catch composition varies according to the strength of year-classes recruiting to the exploited stock. The most abundant year-classes of southern Newfoundland cod have been observed to occur in hydrologically cold years. The Grand Bank is the southern limit of distribution of commercial cod stocks. With the cooling of water masses, environmental conditions approach the optimum, i.e. those typical of the central part of the range of this species. On the other hand, haddock of the Grand Bank are near their northern limit of distribution and conditions favorable for this stock occur in hydrologically warm years. Hence, on the Grand Bank the abundances of cod and of haddock fluctuate inversely. The recent 5-year period has been characterized by a rise in cod abundance and a decrease in haddock stock.

In subarea 1 (West Greenland) stocks of cod are subject to large year-to-year variations due to violent year-class fluctuations. Stronger cod year-classes in the West Greenland area seem to appear in years when poorer year-classes occur in the Barents Sea, and vice versa. For example, West Greenland cod produced outstanding year-classes in 1960, 1961, 1965, and 1966, Barents Sea cod in 1963, 1964, and 1970. Results of young cod surveys in the Barents Sea can, to some extent, be used as an indication of the strength of year-classes in the West Greenland cod. Thus, on the opposite sides of the Atlantic Ocean not only oceanographic but biological processes seem to follow contrary trends. A further study of this phenomenon could not only help in forecasting the state of stocks, but might lead to redistribution of fishing effort between the western and eastern sides of the North Atlantic.

At the 22nd ICNAF meeting in 1972 the Assessments Subcommittee summarized the present state of ICNAF cod stocks and recommended catch quotas for 1973 (Table 5). The assessment of stocks and provision of advice concerning catch quotas are most complicated problems. When dealt with in various scientific committees and at plenary sessions of international fishery bodies they provoke lively discussions, and agreements on these matters are by no means easy to reach. The major difficulty is accurate assessment of the size of stocks, and the attention of fishery research bodies should be focussed on further improvements in methods of assessing stocks and estimating catch quotas. Accordingly, it is essential that both national and international investigations on these matters should be intensified. Recent experience shows that good results can be obtained through systematic quantitative young fish surveys, trawl and echo surveys, and surveys of spawning grounds and quantities of eggs laid. The size and age composition of commercial stocks, size of recruitment, and level of fishing mortality should be kept under regular review. Clearly, no reliable forecasts of the state of stocks can be made without a comprehensive study of hydrographic conditions in the fishing area, which makes it obvious that fishery investigations should be accompanied by hydrographic surveys not only in the fishing area proper but in the entire oceanic area affecting the state of the stocks and distribution of commercial species.

Management of Sea Herring Fisheries in the Northwest Atlantic[1]

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Regulatory measures for herring set by the International Commission for the Northwest Atlantic Fisheries (ICNAF) represent an important milestone in international fishery regulation because for the first time, they provide for national quotas in addition to a total catch limitation.

The first regulatory measures were proposed in January 1972 to be effective that same year. In January 1973, the effects of the 1972 catch on the stock were evaluated, national quotas for 1973 were proposed, and conditional allowable catches for 1974 were proposed depending on stock size at the end of 1973. The 1972 catch, which according to preliminary statistics was within the total allowable catch, caused a further decrease in stock size. The effectiveness of the proposed 1973–74 quotas in increasing stock size depends on the sizes of the 1970 and 1971 year-classes entering the fishery in 1973 and 1974.

Major problems in negotiating these regulations were caused by biological and socioeconomic factors. Biological factors included: population structure — several stocks involved, and parts of them are in nonconvention waters; assessment of effects of fishing — difficult because of rapid fishery development and because there are separate fisheries on adults and juveniles; fishery status — reductions up to 64% from 1971 catches required to prevent further spawning stock decreases. Socioeconomic factors included: allocation — general principles not previously applied, complications from new entrants, newly developing fisheries, and territorial-water fisheries; non-members; immediate action — normal procedures would prevent effective control in 1972; nonconvention waters — significant portions of the fishery not under ICNAF control; economic impact — severe reductions in existing fisheries and curtailment of developing national fisheries; administration — control technically difficult because of species and size mixture.

Solutions to these problems arrived at by ICNAF are discussed, and seven general requirements for rational management are derived: adequate fishery statistics; assessment of effects of fishing; clearly defined objectives; workable techniques of regulation; principles for allocation; effective international inspection; effective enforcement.

Les mesures prises par la Commission internationale des pêches de l'Atlantique du Nord-Ouest (CIPAN) pour réglementer la pêche du hareng représentent un jalon important dans la réglementation halieutique internationale puisque, pour la première fois, elles fixent des contingents nationaux tout en limitant les captures totales.

Les premières mesures de réglementation ont été proposées en janvier 1972 et devaient entrer en vigueur cette même année. En janvier 1973, on a évalué les effets des captures de 1972 sur le stock, proposé des contingents nationaux pour 1973 et proposé un niveau admissible pour les prises de 1974 en fonction de l'état du stock à la fin de 1973. Les captures faites en 1972, qui — selon les statistiques préliminaires — ont été en deça des prises totales admissibles, ont entraîné un ultérieur déclin de la dimension du stock. La mesure dans laquelle les contingents proposés pour 1973–74 contribueront à l'accroissement de la dimension du stock dépend de la taille des classes d'âge 1970 et 1971 entrant dans la phase exploitable en 1973 et 1974.

Lors de la négociation de cette réglementation, les principaux problèmes ont été associés à des facteurs biologiques et socio-économiques. Facteurs biologiques: structure de la population — plusieur stocks sont en cause et ne se trouvent pas en totalité dans la zone de la Convention; evaluation des effets de la pêche — cela a été difficile en raison du développement rapide des pêcheries et du fait que celles-ci sont spécialisées les unes dans la capture des adultes et les autres dans celle des juvéniles; situation des pêcheries — des réductions allant jusqu'à 64% par rapport aux captures faites en 1971 étaient nécessaires pour prévenir une nouvelle diminution des stocks de reproducteurs. Facteurs socio-économiques: allocation des contingents — des principes généraux n'avaient pas été appliqués précédemment ; l'arrivée de nouveaux exploitants, la création de nouvelles pêcheries et l'exploitation de pêcheries installées dans les eaux territoriales ont com-

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pliqué la situation; non-membres; action immédiate — les procédures normales auraient empêché un contrôle effectif en 1972; eaux situées hors de la zone de la Convention — d'importantes parties de la pêcherie ne relèvent pas de la CIPAN; incidences économiques — réductions graves dans les pêcheries existantes et ralentissement des opérations des pêcheries nationales en voie de développement; administration — le mélange de poissons appartenant à des espèces différentes et de tailles diverses rendait le contrôle techniquement difficile.

Les formules trouvées par la CIPAN pour résoudre ces problèmes sont décrites, et sept spécifications générales pour un aménagement rationnel sont élaborées: statistiques halieutiques adéquates; evaluation des effets de la pêche; Objectifs clairement définis; techniques pratiques de réglementation; principes d'allocation des contingents; inspection internationale efficace; mise en oeuvre efficace de la réglementation.

La regulación de la pesca del arenque, establecida por la Comisión Internacional de Pesquerías del Atlántico Noroeste (CIPAN), constituye un hecho importante de la reglamentación internacional de la pesca ya que, por primera vez, fija cupos nacionales, y limita las capturas.

Las primeras medidas reguladoras fueron propuestas en enero de 1972 y entraron en vigor en el mismo año. En enero de 1973 se evaluaron los efectos que las capturas de 1972 habian tenido en las poblaciones y se propusieron cupos nacionales para dicho año y, para el siguiente, se indicaron las posibles capturas, con caracter condicional, segun el volumen de las poblaciones a finales de 1973. Las capturas de 1972, que de acuerdo con las estadísticas preliminares se situaban dentro del total permisible, fueron causa de que disminuyera más el volumen de las poblaciones. El efecto de los cupos propuestos para 1973/74 en el aumento de las poblaciones depende de las tallas de las clases anuales de 1970 y 1971 que entran a formar parte de lo pescado en 1973 y 1974.

Los principales problemas al negociar estas reglamentaciones tuvieron su origen en factores biológicos y socioeconómicos. Los factores biológicos incluían: estructura de la población — se trata de diversas poblaciones y partes de ellas están en aguas no convencionales; evaluación de los efectos de pesca — ello fue difícil debido al rápido aumento de la pesca y porque se pescan por separado los adultos y juveniles; condición de las pesca — se exigió una reducción de hasta un 64% con respecto a las capturas de 1971 para evitar que disminuyera aún más la población en desove. Los factores socioeconómicos incluían : asignación — anteriormente no se habían aplicado principios generales, los nuevos participantes, las pesquerías de explotación reciente y la pesca en aguas territoriales han complicado los asuntos; no miembros; medidas inmediatas — los procedimientos normales impedirían la toma de medidas efectivos en 1972; aguas no convencionales — partes importantes de las pesquerías no están bajo control de la CIPAN; repercusiones económicas — graves reducciones de la pesca actual y limitan la creación de industrias pesqueras nacionales; administración — el control fue técnicamente difícil debido a la mezcla de especies y tallas.

Las soluciones que para estos problemas logró la CIPAN se tratan y dimanan siete requisitos generales para la reglamentación racional: estadísticas de pesca correctas; evaluación de los efectos de la pesca; objetivos claramente definidos; técnicas viables de reglamentación; principios para la asignación; inspección internacional efectiva; ejecución efectiva.

REGULATORY measures for the Northwest Atlantic herring fisheries were first proposed by the International Commission for the Northwest Atlantic Fisheries (ICNAF) in January 1972. The resolution called for them to be put into effect immediately by member nations; they came into force on September 15, 1972. The agreement of member countries to propose such regulations, and their acceptance of the management scheme, was a significant achievement.

In January 1973, adherence to the regulations and the effects of the 1972 catch were evaluated. National quotas for 1973 were set and proposals for catch limitation in 1974 depending on results of the 1973 regulations were included. The effectiveness of the management scheme is outlined in detail in the last section. Briefly, the 1972 catches caused a further decrease in the stock of adult herring aged 4 years and older. The proposals for 1973–74 will be effective in increasing stock size only if recruitment in these years is greatly improved over that of the last 3 years.

The background and events leading to these agreements are summarized in this paper, because the problems that had to be overcome encompass most of those which might be encountered in other situations.

Negotiation of Catch Quotas

The proposals agreed to in 1972 are given in the *Report of the Special Meeting on Herring — January–February, 1972; Proceedings No. 4, Appendices I-VI* issued by the ICNAF Secretariat. In brief, they consist of the following major actions:

Setting catch quotas for three of the five major stocks of herring;

Allocating quotas by national shares;

Setting a minimum size limit for the taking or possession of herring;

Resolving that: coastal states be urged to take action to protect stocks and limit catches of juveniles within territorial waters; governments take action to ensure effectiveness of regulations in 1973; governments take action to regulate fisheries in non-convention waters into which one stock migrates;

Specifying that the Commission shall set quotas for fishing in 1973 at a special meeting in January, such that the level of catch will neither further reduce already low spawning stocks nor reduce yield per recruit during 1973;

Specifying that governments should ensure that catches are recorded by vessels on a daily basis, including discards and disposition of catch.

These proposals were formulated by a small management working group which was chaired by Dr. A. W. H. Needler of Canada. The group started nearly continuous sessions on February 2, 1972. In adjourning on February 7, the chairman noted that this was the first time national allocation of catch quotas had been effected in a multination fishery. The protocol to the Commission which broadened the scope of actions that could be taken by ICNAF, including national allocation, had come into effect on December 15, 1971, just 1 month before the special meeting.

An effective management scheme required solutions for a number of difficult problems caused by biological and socioeconomic factors. A good share of the latter were generated by the former.

Problems of a Biological Nature

POPULATION STRUCTURE

Herring in the Northwest Atlantic are divided into five major unit stocks (Fig. 1). At the time of the meeting of the working group, the status of these stocks varied in significant degree and thus an effective management scheme required separate quotas. At the same time, all stocks had to be regulated to prevent diversion of effort from regulated to nonregulated stocks, which would just exacerbate the situation. Juveniles (1- and 2-year-olds) of all the stocks (probably excepting that on Georges Bank) are distributed and fished inshore in nonconvention waters by coastal nations, while international fisheries are conducted offshore, primarily on spawning stocks. Thus, effective management also required regulation of fisheries not covered by the Convention, which also complicated the problem of allocation of allowable catches. In addition, the Georges Bank stock migrates southward into nonconvention waters, but outside the present coastal state contiguous fishing zone. Thus, effective management required regulation of catches in an area where legal jurisdiction was lacking.

ASSESSMENT OF EFFECTS OF FISHING

The Convention now provides for regulation based on "technical" needs as well as conservation needs, but the Commission has a tradition of strongly emphasizing the latter as a basis for regulation. Regulatory measures are often delayed by the difficulties in establishing the biological status of the fishery. Biologists had difficulty in establishing the effects of fishing and the requisite management

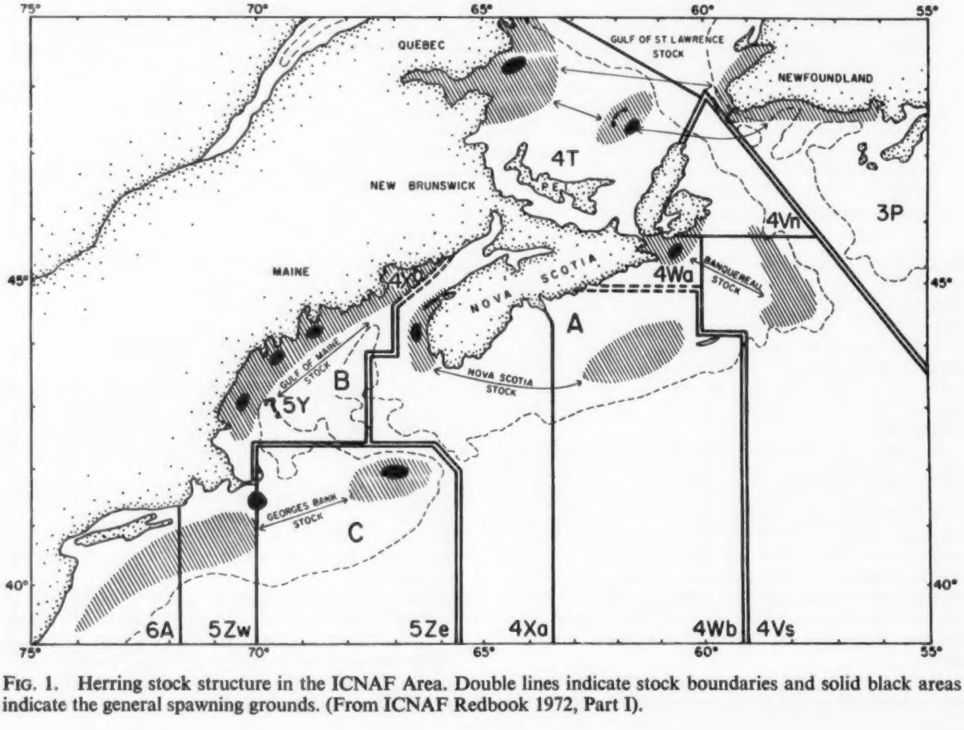

FIG. 1. Herring stock structure in the ICNAF Area. Double lines indicate stock boundaries and solid black areas indicate the general spawning grounds. (From ICNAF Redbook 1972, Part I).

statistics (e.g. prediction of recruitment and harvestable surplus yields), to the degree of precision and accuracy deemed necessary by the Commissioners, because of rapid development of the international herring fisheries, lack of satisfactory data, and the complex nature of stock distribution and fisheries. For example, the Georges Bank herring fishery developed on a virgin stock and overfished it within 9 years, before a scientific study could establish the productivity and maximum sustainable yield (Table 1).

The inshore juvenile fishery and adult fishery are to a large extent separate, and are conducted with different gears. Thus they posed the problem of determining the effects of two fisheries and the interaction between them. For example, in the Gulf of Maine the catch of a ton of 2-year-olds is equivalent in numbers to a catch of about 3 tons of adults (4–6 year-olds). On the other hand, the magnitude of the spawning stock affects the subsequent abundance of juveniles to some degree. This presents an interesting case of evaluating trade-offs.

FISHERY STATUS

The objectives of the proposed management scheme were to prevent further declines in size of spawning stock and to maximize yield per recruit by preventing overly intensive fishing and by reducing the harvesting of small fish. Although the broader objectives of increasing spawning stock size to ensure faster and more probable recovery of maximum productivity, and of enhancing the economic return, appeared desirable and necessary, the less difficult objectives were accepted as the best possible for a first step. To attain these objectives required the setting of quotas for 1972 which meant a reduction from the previous year's catch of 14% for the Nova Scotia fishery, 44% for the Gulf of Maine, and about 64% for the Georges Bank fishery (Table 2). The latter figure stimulated extended discussion of the accuracy of the assessment.

Problems of a Socioeconomic Nature

In most cases of fisheries regulations in ICNAF, the socioeconomic factors have been the determinants of the final agreement. This was true in the herring proposals, although consideration of conservation needs was, perhaps, relatively more important than in previous deliberations because of the seriousness of the situation. These factors included the following:

ALLOCATION

Over the past few years in its Standing Committee on Regulatory Measures, ICNAF had discussed general principles of management techniques and national allocations, achieving some consensus. Of primary concern in allocation were considerations of historical performance, developing fisheries, new entrants, and coastal state needs. The latter was, of course, of particular importance in the problem of how to deal with territorial water fisheries. The nations with no past participation insisted that they not be excluded from entry in principle, even though most did not anticipate such entry.

NON-MEMBERS

Several countries that were not members of ICNAF were fishing in the area. The German Democratic Republic, in particular, had developed a significant fishery for herring, and could not be approached through any formal channels. If they continued the fishery in 1972 at

TABLE 1. Herring landings (thousands of metric tons) by area (stock), 1961–71. (A=adults, J=juveniles); (4Wa=Chedabucto Bay area; 4Wb=Div. 4W offshore; 4Xa=Div. 4X offshore and Nova Scotia inshore; 4Xb=New Brunswick side of Bay of Fundy.)

Year	Subarea 3	Div. 4RST	Div. 4Vn	Div. 4Vs	Div. 4Wa	Div. 4Wb	Div. 4Xa		Div. 4Xb		Div. 5Y		Div. 5Z	Subarea 6	Total
							A	J	A	J	A	J			
1961	4	20	← 3 →				← 58 →				3	23	68	–	179
1962	5	36	← 12 →				← 68 →				1	69	151	–	342
1963	6	42	1	–	2	3	25	5	4	32	1	67	97	–	285
1964	4	44	0	–	2	1	37	12	5	40	8	20	131	–	304
1965	8	49	0	–	1	6	65	12	5	44	3	31	41	–	265
1966	23	43	0	–	1	2	122	8	6	55	4	24	137	6	431
1967	78	69	0	0	1	1	128	13	6	50	24	19	216	4	609
1968	145	119	4	16	1	2	130	13	9	75	34	29	345	29	951
1969	146	158	11	107	28	13	82	11	4	43	32	23	253	54	965
1970	135	181	7	27	29	60	76	12	3	30	45	11	207	40	863
1971	118	146	11	7	54	29	46	10	1	12	42	8	221	42	747
1972[a]	49	50	12	1	25	23	52	14	4	52	35	20	126	12	475
Stock	Gulf of St. Lawrence		Banquereau			Nova Scotia			Gulf of Maine				Georges Bank		

[a] Preliminary statistics; nonmember catches estimated.

TABLE 2. Allocation of 1972 herring quotas and 1971 catches (adults only — in thousands of metric tons).

Country	Stock			Total	1971 catch
	Georges Bank 5Z and 6	Gulf of Maine 5Y and 4Xb	Nova Scotia 4Xa and 4Wb		
Canada	5.8	6.0	35.7	47.5	74
Germany, Fed. Rep.	31.6	2.5	–	34.1	57
Poland	49.4	–	–	49.4	88
USSR	48.2	–	26.3	74.5	110
USA	4.0	21.0	–	25.0	25
Japan	1.2	–	1.0	2.2	3
Romania	0.6	–	–	0.6	1
Other contracting govts.	1.0	0.25	1.0	2.25	0
Total quota	150.0	30.0	65.0	245	–
Total allocated	141.8	29.75	64.0	235.55	–
1971 catch					
Member govts.	234	41	75		350
Non-members	33	2	0		27
Total	267	43	75		385

the same levels as in 1971, they would catch more than the indicated allocations given to many member countries, which were faced with reduced catches.

IMMEDIATE ACTION

The special meeting was called in January 1972 to be able to implement management in the current year. Normal procedures for bringing regulations into force meant a possible 9-month delay and, therefore, no effective control in 1972. Governments thus faced the need for putting regulations into effect before the formal, official, national mechanisms could act. The USA in particular requires the action of ICNAF to promulgate domestic laws regulating its nationals on the high seas. It was questionable if some of the countries could legally satisfy this requirement.

NONCONVENTION WATERS

A similar legal situation arose because of the need to regulate catches in the waters south of the Convention area. Without the jurisdiction of ICNAF, legal control of fisheries in this area was a serious problem for some member governments.

ECONOMIC IMPACT

Several major fishing countries depend heavily on the herring fishery. Despite the longer run consequences (i.e. beyond 2 years) of no regulations, which likely would be total collapse and an indeterminant period of recovery, the immediate reduction in catch of up to 60% (for the Georges Bank stock) posed a severe, immediate economic threat. The countries with expanding fisheries based primarily on the herring stock also faced severe consequences.

ADMINISTRATION

Many problems arose related to technical difficulties in control of the fishery to meet the regulatory measures. Eliminating the catch of fish less than nine inches would prove difficult because of the high degree of mixture with larger fish at some times and in some areas, and because discarded fish would not suvrive. Incidental catches would also create difficulties in keeping the catch within the quota. Herring are often mixed with other species, particularly alewives, bluebacks, and mackerel, at least closely enough to make avoidance by the fisherman difficult. Total fleet capacity in the area was so large in comparison to that needed to harvest the herring quotas, that estimating the probable catch outside of directed fisheries could not be very accurate. Hence, it would be difficult to set the closure of the directed fisheries in time to prevent exceeding the quota. This aspect also increased the difficulty of enforcement, and did not permit nations to make direct observations to verify conformance to the regulations. Several countries had made formal reservations to the existing international inspection scheme, and did not permit examination of catches below decks. This meant that direct observations of amounts of incidental catches and lengths of fish were not practical.

ICNAF Solutions

The major part of the international fishery is conducted on adults, and defining the unit stocks for management was not a serious problem. It was stipulated that regulations for all three stocks must be effective at the same time, and this prevented serious adverse effects of possible diversions of effort, and maximized achievement of objectives even in the event stock structure was different from that which the evidence indicated at the time.

The problem of nonconvention waters was handled by Resolution, which invited, urged, requested, and called on Contracting Governments to ensure that appropriate conservation measures were taken in territorial fisheries, and that regulations were also extended to nonconvention, nonterritorial waters. Preliminary information on catch indicates that fishing in these nonconvention waters proved not to be a significant matter in the first year, because such catches were not great enough to obviate the desired limitations. However, Canada and the USA at least, could not implement resolution because promulgation of a domestic law proved intractable. Thus, some further actions are needed to solve this aspect.

There was initially a severe questioning of the accuracy of the stock assessments. However, it was finally conceded that these provided a basis for action. It was emphasized that implied inaccuracies had to be clarified by the questioning governments by supplying relevant data and analysis.

There was an initial approach to allocation based on previously developed principles. The working party quickly adopted the principle of equal sacrifice based on reductions from previous years' catches. This was done with agreement that it had no precedence or prejudice for future allocations. But the USA insisted that its share be based on need and capacity, and not be related to the percentage reductions implied above—in other words, an unequal sacrifice. The rationale was that the coastal fishermen had no alternative grounds as they could not reach them, or alternative resources, partly because of the increasingly heavy foreign fisheries. This was accepted, but was not construed by others as a precedent for giving coastal state preference.

A small share was allocated for incidental catches, and to avoid the appearance of totally excluding new countries from any possibility of entrance. Problems created by nonmember fishing countries could not be dealt with directly. Where their catches were significant, an amount was taken off the top of the agreed allowable catch before allocations were made. These amounts were probably not adequate, and may cause the quotas to be exceeded. Some trading was inevitable, and at times the whole agreement seemed to hang on finding 500 or 1000 tons of fish to satisfy a principle or a home-front demand.

The severity of the required reduction, particularly on Georges Bank, apparently caught some governments totally unprepared. It should not have, because a preliminary assessment established at the June 1971 meeting indicated that to halt the spawning stock decline the catch from the Georges Bank stock in 1972 would be only about 100,000 metric tons. An early proposal to limit the catch to 150,000 tons was readily accepted by Canada, Japan, Germany, USSR, and France. But the USA and Poland did not accept this, for opposite reasons. The assessment report indicated that 90,000 tons was the upper limit to the catch required to meet the objective of not reducing the spawning stock during 1972. The situation was resolved by accepting a 150,000 ton catch, but stipulating that the 1973 quota must be set at the level required to achieve the objective of protecting the spawning stock as calculated by the Research and Statistics Committee. Given the circumstances, the higher catch seemed a first step that was better than none. One must consider that regulation of the other two stocks, over which fewer problems in agreement arose, was dependent on agreement for Georges Bank.

Enforcement was left to each government. Governments were to conduct fisheries such that the directed and incidental catches equalled the allocated quota.

Requirements for Rational Management

The experience of ICNAF in attempting to develop management schemes has indicated that several general requirements must be met to achieve effective control of fisheries. These are listed in the order of the sequence in which they usually are considered: adequate fisheries statistics; assessment of effects of fishing; clearly defined objectives of management; workable techniques of regulation; accepted principles for allocation; effective international inspection; effective enforcement.

These of course are not absolutes. They must be defined, in general, along that thin line which discriminates in appropriate measures between flexibility and rigidity. Specific applications require a tailoring of the general guidelines to get the best fit, but the principles should remain intact. This would limit the influence of special interest and assure the smaller participants that the regulations supply a general benefit.

I have listed fishery statistics separately because this requirement usually gets too little consideration. Good statistics are the fundamental basis of management. Their proper quantity and quality should be defined early, and the specific requirements of each government should be an inherent part of the management scheme. In particular, this requirement should include a comprehensive, seasonal survey of the resource by research vessels. This is mandatory for adequate assessment and monitoring of the fishery status. But there do not seem to exist in treaties the requisite words or a mechanism which can lead to meeting this requirement. Perhaps the distinguished members of this conference can consider the necessary means to achieve this.

Assessment of the effects of fishing supplies information not only for defining the conservation requirements, but also for defining objectives, estimating economic effects, defining alternate means of regulations, evaluating consequences of various proposed actions, and setting up monitoring procedures. The assessments may be done either by a commission staff of scientists (e.g. Inter-American Tropical Tuna Commission) or by means of a research committee and associated working groups and subcommittees composed of scientists of member governments and other consultants (as in ICNAF). Either system is subject to limitations based on the amount of money or number of people that governments are able and willing to provide. The commission staff has advantages because costs are usually distributed among member governments in proportion to fishery participation, because research activities are easier to coordinate, and because international objectivity is easier to maintain. In regard to the latter point, after having participated in the various assessment working groups and committees of ICNAF (and jointly with ICES) for 10 years, and having been chairman of the ICNAF Assessment Subcommittee for the 3 years just past, I conclude that scientists of the member governments have performed their tasks without significant national bias. This may be related to the seriousness of the actions which are implied by the results of research. Effects of this are being severely tested in ICNAF. The committee system has an advantage in providing scientists who are familiar with the fisheries involved. This is important in an area like the ICNAF Convention waters, which encompass many diverse fisheries.

It is safe to say that the benefits of management will be proportional to the amount of attention given to provision of adequate statistics and accurate assessment of the effects of fishing. At present, governments must either be willing to provide more support for these or to make decisions under greater degrees of uncertainty. This aspect needs a decision-theoretical treatment to optimize the strategy. This approach would provide a basis for deciding whether more research would "pay off," in the sense of achieving an outcome that was probably better than an alternate outcome which would be certain (or nearly so) without additional investment.

A good management scheme obviously depends on defining reasonably precise objectives as well as developing a rational means and desire to achieve them. It is surprising how often this is not done. It has been my experience that this lack has caused scientific reports to be less useful in providing information that the commissioners need to make decisions. Somewhat in frustration at not being able to communicate effectively, the Assessment Subcommittee of ICNAF recently defined four levels of fishing mortality which could be related to a range of management objectives (ICNAF Redbook, Part I, 1972):

F_{max} — The fishing mortality that will give the maximum yield per recruit

$F_{0.1}$ — The fishing mortality at which the increase in yield per recruit resulting from adding one unit of mortality is 1/10 of that achieved in a lightly exploited stock.

Replacement catch (harvestable surplus) — the annual catch that will not change the stock size over the year

Maximum sustainable catch — the largest, long-term average annual catch taking into account the average annual recruitment.

Advice on the current fishing rate can be related to the above values, as can the objectives of management (e.g. economic optimums tend to be achieved at $F_{0.1}$). An important objective in management must be to provide options which allow countries to satisfy particular needs. Thus, certain types of fish may be more desirable to one country than another, even in lesser amounts than could be obtained from an alternative species. The objective of maintaining or improving the "quality of life," which by local definitions might include certain special products or small-boat fisheries, may require the harvest rate to be less than the maximum.

Techniques of regulations offer many options. The technique to be used should be selected to maximize achievement of objectives and minimize interference with fishery operations. Scientists can help with the former. A major way is to control effort or catch. Control of effort is most efficient because catch quotas achieve the same thing in a less direct manner. Also, if in fact a reduction in fishing mortality is required, the catch quotas to achieve this would generally have to be set at a level that is lower than that corresponding to the catch resulting from direct effort reductions. This is because if the catch per unit effort drops, the effort to take the catch quota is greater and the desired reduction may not be achieved. The opposite could happen, of course, but the consequences of the former mistake are much more severe; also where overfishing is occurring, the population will be moving downward and the fishing effort will tend to increase, to compensate, so that the catch would decrease even if effort were held at the same level.

With a national allocation, member governments are in a position to control national fisheries in almost any manner they desire. Thus, if they can regulate the national effort, economic benefits of either international effort or catch quotas are much the same.

The principles of allocation are largely concerned with social aspects, and these have been explored by ICNAF for some years. It appears that a system of national allocations is mandatory for agreement on regulations. It tends to minimize competition, and allows countries to conduct fisheries in ways which maximize the benefits of management. The manner in which allocation takes place will probably always have to allow for negotiations, but the task would be easier and perhaps fairer if some general principles could be agreed upon.

International inspection and enforcement determine the effectiveness and endurance of a management scheme, no matter how well conceived. The primary components are adherence to the regulations and credibility among nations. Management will not succeed if it is not clearly and practically verifiable that everybody is playing the same game. International enforcement, as opposed to inspection, would provide to some extent the required credibility, but even with this arrangement there must be a high degree of "self-evidence" which will promote acceptability. This will also improve the ability to monitor the effects and to adjust regulations to assure that objectives are being achieved.

In reality, however, the concepts of scientific validation and social validation must be separated. The former in many cases is not "transparent" enough to satisfy the public and private sectors, even when it is adequate.

The type of regulatory measures will affect this to some degree. For example, it is easy to count vessels, and a decrease or increase here is generally observable and demonstrable, relative to the increase or decrease in amount of fish actually caught. In some instances a mutual exchange of observers on board the fishing vessels may be required, as has been the practice in some management schemes. In any event, the aspect of credibility must be given thorough consideration.

Management of the herring stocks to achieve the maximum long-run yield needs improvement in some of the requirements discussed above. These include fisheries statistics and the assessment of the strength of recruits and distribution of juveniles. The international inspection scheme must be liberalized to allow inspection of catches. Incidental catch problems cannot really be solved until some control of total effort on an area basis is achieved. This is now being considered by ICNAF, but is beyond the scope of this paper.

Effectiveness of the Management Scheme

The January 1972 assessments for the Georges Bank stock indicated that a catch of 95,000 tons in 1972 would be about the replacement yield. A quota of 150,000 tons was set. Preliminary statistics indicate the 1972 catch was within the quota, although two countries' catches are not yet known. The effect of this catch was to reduce the spawning stock from 240,000 tons to 158,000 tons at the beginning of 1973, a 34% decrease. The Assessment Subcommittee has indicated that a stock size of about 500,000 tons would probably provide the maximum sustained yield of about 250,000–300,000 tons.

In January 1972, the Commission had resolved to set quotas in 1973 such that neither spawning stock nor the yield-per-recruit would decrease further. In view of the decrease and now very low stock size, this did not, at the recent meeting, seem to be an adequate objective of management.

The allowable catch for 1973 must be based on reaching some objective; but this catch was difficult to assess because of uncertainty about the size of the 1970 year-class which would be recruited in 1973. In reality, one could only make a qualified judgment and a rather wide range of allowable catches resulted. The Commission chose to set as an objective rebuilding the stock to at least 220,000 metric tons by the end of 1974. It decided to set the allowable catch in 1973 at 150,000 metric tons, to be reduced in 1974 if information indicated the objective could not be reached; and not to be increased unless the populations would reach optimal levels. Thus it seems that if recruitment is good over the next 2 years, the spawning stock may be significantly increased. If not, the management scheme will not produce substantial improvement after 3 years of operation.

In the Gulf of Maine, the situation is not quite so bad, but the 1972 limitations were ineffective in holding the line. The 1972 allowable catch of 35,000 tons was exceeded by at least 5,000 tons. The spawning stock declined from about 70,000 tons to about 50,000 tons. For this stock, the stock size estimated to produce maximum sustainable yields is about 110,000 tons. Here again, the allowable catch in 1973 depended on recruitment of the 1970 year-class, but this was somewhat better known. For the objective of reaching a stock size of 60,000 tons by 1975, the 1973 allowable catch was set at 25,000 tons, and the same constraints applied for the 1974 catch as described above. The same prognosis about effects of management applies here as for the Georges Bank stock.

Less information was available for the Nova Scotia stock. It was judged to be in good condition in 1972, with good recruitment expected in 1973. Thus, the 1973 allowable catch was set at 90,000 tons, up from 60,000 tons in 1972. The actual catch in 1972 was, however, 75,000 tons at least.

There was no change in national allocation procedures from that applied in 1972. The same problems of date of entry and regulation in nonconvention waters remain; i.e. regulation becomes immediately effective for 1973 and in nonconvention waters only if member governments essentially volunteer to make it so.

Thus, management of the herring fisheries might be termed nonsuccessful. It is only fair to allow the first year for experience and for solving unexpected problems, and to await the subsequent years as the time for more strict evaluation of achievements. In the Northwest Atlantic herring, however, the condition of some stocks was so poor before action was taken that a year's grace was not available. In part, success must be judged on lessons learned and applied to further problems. The second year's negotiations did result in a more firmly defined objective, and commitment to achieve it.

Report on Technical Session IV — Section 5

General Review

1. The North Atlantic produced 15 million metric tons of fishery products in 1970, almost equal to landings in the North Pacific. There is a long history of fishing in this area, and cooperation on regulations dates back to 1882. The International Council for the Exploration of the Sea (ICES) was founded in 1902. The International Commission for the Northwest Atlantic Fisheries (ICNAF) is concerned with both research and regulation, and the North East Atlantic Fisheries Commission (NEAFC) with regulation only, receiving its scientific advice from ICES. There is also an arrangement between the Baltic countries concerning salmon.

2. Fishing fleets consist of a large number of inshore and coastal vessels, many medium vessels of 150 to 500 grt, and deep-sea fleets. Some of the latter are highly mobile, with processing done on the grounds.

3. Although the North Atlantic is still a major producer of high-quality fish, there have been disturbing developments recently. In the northwest, cod landings showed decline after 1968 because of poor recruitment following earlier intensive fishing; other factors include long-term climatic changes and adverse ice conditions. Herring catches fell after 1968, again because of poor year-classes and previous heavy fishing. Haddock on Georges Banks decreased drastically between 1966 and 1969.

4. In the Northeast Atlantic there has been a small overall recession in the fishery and a pronounced change in species composition. Herring fishing was very good up to 1967 following the introduction of the power block for purse seines, but later the stocks practically collapsed. The total catch remained almost the same due to the shift to other species such as capelin.

5. North Sea demersal fisheries are in better shape than previously following the adaption of mesh regulations and the appearance of exceptional year-classes of haddock. But herring have decreased greatly since the development of intensive trawling on their spawning grounds. In the Barents Sea intense fishing makes the stock heavily dependent on varying success of recruitment. The fleets move from one stock to another according to fish availability. There is limited margin for increased production in the future.

Adequacy and Timeliness of Biological Information

6. The scientific advice available to both management bodies is reasonably good, although the institutional arrangements of the two Commissions (ICNAF and NEAFC) differ. In both cases there are close contacts and dialogues between scientists and decision makers, so that each group is responsive to the needs of the other. Services include standard data reporting on Commission problems. Research is carried out by individual nations and is coordinated by numerous scientific working groups.

7. Although the institutional arrangements and scientific advice are generally satisfactory there is still room for improvement. Many new problems have developed during the past few years. In particular, knowledge is not adequate concerning recruitment, rate of exploitation, biological inter-reaction between different species, direct measurement of the abundance of fish, and the energy flow through the ecosystems. Perhaps the outstanding problem is to ascertain the relative contributions of natural causes and of fishing to observed failures of recruitment. There is, however, a problem of timing. It is increasingly difficult for the scientists to provide advice in time for ICES meetings and NEAFC requirements.

8. In spite of considerable improvement, fishery statistics are still inadequate. It was suggested that the plan used by meteorologists could be followed: the necessary data required and proper methods of collecting them would be spelled out in detail.

Mechanisms for Handling Scientific Information

9. The structure and mode of operation of ICNAF, ICES and NEAFC were described in detail. ICNAF combines the functions of coordination of investigations and promulgation of regulations, whereas in the eastern region these functions are divided between ICES and NEAFC. Both systems are working well.

Performance of the Commissions

10. Originally both Commissions could only regulate the size of mesh used in nets, and the size of fish that could be landed. While there have been positive benefits from increased mesh sizes, these have proved insufficient. Very recently ICNAF was empowered to set national quotas, by species and area, for stocks being fully utilized. NEAFC does not yet have authority to impose quotas, but is making administrative arrangements toward this.

11. This important step has been made possible by changing attitudes among both governments and fishermen, triggered by the steady growth of fishing capacity, the disastrous failure of some stocks, and threats to others. The system of quotas adopted in 1972 allowed 10% each for newcomers and the special interest of coastal states. Division of the remaining 80% was equally on the basis of average catch over 10 years and on average catch over 3 years. Of course this cannot be considered as a universe formula for all future quota regulations. The Commission have performed as best they could under their legal powers and the economic and social circumstances. Their

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recent actions show that they are determined to catch up with the increasing number of urgent conservation requirements.

Systems for Enforcement and Control

12. International inspection was first proposed in 1963 and was adopted in 1969. Between these years governments were encouraged to exchange fishery inspectors on the high seas. This has helped to reduce mutual suspicion. Inspectors are authorized to stop and board vessels and to inspect nets and catches. They then report infractions to the Commission and to the country concerned. Any legal action is the responsibility of the country where the vessel is registered. It is intended to amend the scheme to allow control of closed areas and seasons and other possible regulations restricting fishing effort.

Management of Fisheries at the National Level

13. The experience of three countries was described briefly. In Norway the climate for management has improved greatly recently, both in government and in industry. Timely steps have been taken to protect North Sea mackerel. Measures to manage Barents Sea capelin include protection of young fish and spawning areas, and catch quotas. The effects of these measures have yet to be assessed.

14. In France national management has involved the development of bodies with representation from fishermen, plant-owners, conservationists and others. The main emphasis is on fishermen's appreciation of and participation in the regulations.

15. In the Netherlands the sole is very important. Dutch fishermen have introduced the double beam trawler, and while other nations have objected that these harm the bottom fauna and are unfair to traditional gear, Dutch authorities feel that there is no proof of this and that it would be wrong to prohibit an efficient gear.

Recent Trends in Development of New Fisheries

16. Capelin and polar cod catches have increased in the Barents Sea. Capelin are available in the Northwest Atlantic, and exploitation has begun. Grenadiers have an estimated stock of 10 million tons in the North Atlantic, and might provide a fishery of 3 million tons annually. There are also large stocks of blue whiting.

FAO Technical Conference on Fishery Management and Development

TECHNICAL SESSION IV — SECTION 6

Regional and Other Case Studies — Distant-Water Fisheries

CHAIRMAN: A. S. BOGDANOV

Distant-Water Fisheries and Their Relation to Development and Management[1]

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An important proportion of the present world catch of fish (some 12% by weight, and more by value) is taken by long-range vessels. In some areas, e.g. the Northwest Atlantic, the proportion taken by long-range vessels is higher, up to 50%. The operations of these fleets and their effects on the operations of local fishermen have been causes of international friction on a number of occasions.

The ability of long-range fleets to concentrate quickly on a newly exploited resource can mean that severe damage may be done to the resource before the necessary management measures can be implemented, at least by the traditional machinery. Management techniques need to be improved to enable them to react in a more timely fashion to changing fishing patterns (this also applies to local fisheries, where the speed of development is also becoming rapid).

With proper management, long-range fishing is at present the most effective way of harvesting many of the world's fish stocks, and without it there would be a big drop in the total world catch. However, given equal access to modern technology and to better markets, local fisheries with lower capital and running costs are likely to be more efficient at harvesting the resource. In the long run, local fisheries may be expected to replace long-range fleets in most areas. In the short run, the existence of the long-range fleets, by reducing the abundance of the stocks, and hence the catch rates, may inhibit the development of local fisheries, and reduce the success of those already existing. This may be balanced by benefiting from the experience of the long-range fleets as regards the best fishing grounds, seasons, etc.

Une grande partie des prises mondiales actuelles de poisson (12% environ en poids, et davantage en valeur) est imputable aux navires à grand rayon d'action. Dans certaines zones, par exemple dans l'Atlantique Nord-Ouest, la proportion des prises dues à ces navires est plus élevée encore, atteignant jusqu'à 50%. Les opérations de ces flottilles et leurs effets sur celles des pêcheurs locaux ont, à maintes reprises, suscité des frictions internationales.

L'aptitude des flottilles à grand rayon d'action à se concentrer rapidement sur des lieux nouvellement exploités risque d'endommager gravement les ressources, avant que puissent être mises en oeuvre, du moins par les processus habituels, les mesures d'aménagement qui s'imposent. Il est nécessaire d'améliorer les techniques d'aménagement pour qu'elles répondent de façon plus opportune aux structures changeantes de la pêche (cela valant aussi d'ailleurs pour les pêches locales qui connaissent aussi une évolution très rapide).

Grâce à un aménagement convenable, la pêche à grand rayon d'action constitue actuellement le meilleur moyen d'exploiter nombre des stocks ichtyologiques du monde entier et, sans elle, le total des prises mondiales accuserait une chute radicale. A condition de leur permettre aussi d'accéder aux techniques modernes et de leur offrir de meilleurs débouchés, les pêches locales, avec moins de capitaux et de dépenses de fonctionnement, seraient sans doute mieux en mesure d'exploiter les ressources. On peut s'attendre qu'à la longue les pêcheries locales remplaceront les flottilles à grand rayon d'action dans la plupart des zones. Dans l'immédiat, la présence de ces flottilles risque, en appauvrissant les stocks et, partant, en diminuant les taux de prises, d'entraver le développement de nouvelles pêcheries locales et de freiner l'essor de celles qui existent. On pourrait compenser cet inconvénient en profitant de l'expérience des flottilles à grand rayon d'action en ce qui concerne les meilleures zones de pêche, les saisons les plus propices, etc.

Una proporción importante de la actual pesca mundial (aproximadamente un 12% según peso, y más de acuerdo con su valor) la obtienen embarcaciones de gran altura. En algunas zonas, por ejemplo, en el noroeste del Atlántico, la proporción capturada por embarcaciones de gran autonomía es aún mayor,

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llegando hasta un 50%. Las operaciones de estas flotas y sus repercusiones sobre las de los pescadores locales ha sido causa de fricciones internacionales en diversas ocasiones.

La posibilidad que tienen las flotas de gran autonomía de concentrarse rápidamente sobre recursos de reciente exploración significa que pueden causarse daños graves a estos recursos antes de que se pongan en ejecución las necesarias medidas de regulación, al menos por los cauces tradicionales. Es necesario mejorar las técnicas de regulación para que puedan reaccionar de manera más rápida ante los cambios de los sistemas de pesca (esto también se aplica a las pesquerías locales, cuyo desarrollo está cobrando una gran rapidez).

Con una reglamentación adecuada, la pesca con embarcaciones de gran autonomía es actualmente el medio más efectivo de explotar muchas de las poblaciones de peces y sin ellas habría un gran descenso en el total de capturas mundiales. No obstante, permitiendo por igual el acceso a la tecnología moderna y a unos mercados perfeccionados, las pesquerías locales, con un capital inferior y con costos de explotación menores es probable que fueran más eficientes en la exploración de los recursos. A largo plazo, los pescadores locales es de esperar que reemplacen a las flotas de gran autonomía en la mayoría de las zonas. A corto plazo, la existencia de estas flotas con gran autonomía, al reducir la abundancia de las poblaciones, y por ende los índices de captura, pueden inhibir el desarrollo de la pesca local y reducir el éxito de las que ya existen. Esto podría compensarse aprovechándose de la experiencia de las flotas de gran altura por lo que respecta a los mejores caladeros, campañas, etc.

THE operations of distant-water fishing fleets have caused, and are causing, more international argument and conflict than any other type of fishing or, indeed, any other activity of similar economic importance. Disputes such as those between Iceland and other European countries over cod, or between USA and Latin American countries over tuna, have occurred in many parts of the world.

Although the popular view of a distant-water fishery is often of large, highly efficient fleets of the rich developed countries sweeping the seas clean of fish, causing the ruin of the fishermen of the developing country off whose coasts the fishing occurs, this picture is too simple and, in many ways, seriously misleading. Operation of distant-water fleets is not confined to the most developed countries. Several developing countries, such as the Republic of Korea, have such fleets and others such as Ghana and Thailand are increasing their long-range activities. Again, these fleets operate not only in the waters off developing countries. For instance, coastal fishermen of the United States are as ready to complain about the impact on their activities of large long-range fleets (e.g. of USSR) fishing off their coasts as are fishermen of Mexico to complain of the activities of United States tuna or shrimp vessels. Virtually every developed country with appreciable fishery resources has had some long-range operations in its waters. One of the oldest long-range trawl fisheries, which has lasted for some 60 years, is the English plaice fishery off the Murman coast of the USSR.

Finally, it is not certain that distant-water fishing is more efficient than the more local fisheries or that the latter cannot survive against the competition of the long-range factory ship. For example, many long-range vessels cross the northern North Sea but they rarely, if ever, fish there, where the small family-owned vessels of Scotland and Denmark are highly successful. In this area, at least, it is the small (but still efficient) vessels that have driven out the larger ships.

The impact of distant-water fisheries on development of local fisheries and on management of fish stocks is a complex matter. Three aspects may be distinguished: the importance of such fisheries to the countries operating them; the efficiency or otherwise of distant-water fisheries in harvesting the resource, including the question of management; and the effect these fisheries have on the local fisheries.

DEFINITION OF DISTANT-WATER FISHERIES

There is a spectrum of size and range of fishing vessels from the large freezer/factory trawler or mother-ship capable of fishing anywhere in the world, down to the African canoe working off the beach. Some vessels, such as the smaller tuna longliners of Japan or Korea, which clearly must be included as distant-water vessels, are smaller than the larger English North Sea trawlers, generally considered local vessels. A useful definition in relation to discussion of development and management problems, which have important resource aspects, would be to include as local fisheries all those which operate on stocks of fish in the coastal waters of the country concerned. Other fisheries would be considered distant-water fisheries. Thus the British trawl fishery around the Faroe Islands, the stocks of which are separated by deep water from those around the British Isles, would be considered distant-water, while those off the west coast of Scotland would be included in local fisheries, although the distances from the main fishing ports, such as Aberdeen, are about the same.

Other classifications are possible. For example, it may be useful to distinguish a separate category of mid-water fishing. This would include such fisheries as the British fishery at the Faroes, considered under the above definition as distant-water, and those local fisheries of sufficient range for there to be significant interaction between fleets of different countries. These mid-water fleets can give rise to international arguments somewhat similar to those caused by long-range fleets, but with some important differences. For example, the number of mid-water fleets interested in a given resource will be limited and their mobility is less. A major cause of the British dispute with Iceland is the lack of alternative employment for the trawlers currently fishing around Iceland.

Importance of Distant Water-Fisheries

Table 1 shows the contribution, in major sea areas, of local and distant-water fisheries during the past few years. The information on the North Atlantic is good enough to fit the above definition with fair exactness. The detailed data on location of catches in other areas are not so good.

TABLE 1. Catches in thousand tons and, in parentheses, percentage of national total taken by local and distant-water (DW) fleets in different regions of the world.

		Year						
Fishing areas		1964	1965	1966	1967	1968	1969	1970
Atlantic, Northwest	Local	1,665 (49)	1,785 (47)	2,047 (52)	2,080 (52)	2,275 (50)	2,110 (48)	2,170 (51)
	DW	1,725 (51)	1,975 (53)	1,973 (49)	1,950 (48)	2,315 (50)	2,250 (52)	2,050 (49)
Atlantic, Northeast	Local	7,536 (87)	8,224 (85)	8,736 (86)	9,063 (87)	9,411 (92)	9,251 (92)	9,734 (91)
	DW	1,114 (13)	1,396 (15)	1,464 (14)	1,287 (13)	839 (8)	769 (8)	926 (9)
Atlantic, Western Central	Local	1,500 (97)	1,561 (97)	1,210 (95)	1,245 (97)	1,344 (33)	1,435 (99)	1,460 (99)
	DW	50 (3)	49 (3)	60 (5)	35 (3)	16 (1)	15 (1)	10 (1)
Atlantic, Eastern Central	Local	569 (50)	603 (50)	724 (53)	748 (49)	716 (42)	782 (38)	866 (34)
	DW	571 (50)	597 (50)	636 (47)	782 (51)	974 (58)	1,288 (62)	1,714 (66)
Mediterranean and Black Sea	Local	960 (100)	990 (100)	1,030 (100)	1,110 (100)	1,030 (100)	970 (100)	1,170 (100)
	DW	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Atlantic, Southwest	Local	443 (94)	502 (96)	559 (87)	566 (45)	612 (76)	594 (84)	611 (58)
	DW	31 (6)	22 (4)	85 (13)	686 (55)	198 (24)	116 (16)	444 (42)
Atlantic, Southeast	Local	1,583 (84)	1,580 (72)	1,615 (70)	1,978 (75)	2,412 (73)	2,289 (74)	1,620 (66)
	DW	307 (16)	600 (28)	695 (30)	662 (25)	888 (27)	801 (26)	840 (34)
Indian Ocean, Western	Local	1,170 (96)	1,158 (93)	1,241 (90)	1,232 (91)	1,308 (91)	1,350 (30)	1,545 (91)
	DW	50 (4)	82 (7)	139 (10)	128 (9)	132 (9)	150 (10)	145 (9)
Indian Ocean, Eastern	Local	692 (90)	704 (93)	778 (96)	868 (93)	959 (94)	1,076 (96)	1,051 (96)
	DW	48 (10)	56 (7)	32 (4)	62 (7)	61 (6)	44 (4)	39 (4)
Pacific, Northwest	Local	9,920 (100)	10,700 (100)	10,800 (100)	11,160 (100)	12,170 (100)	12,110 (100)	13,030 (100)
	DW	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Pacific, Northeast	Local	659 (44)	640 (44)	661 (40)	476 (25)	473 (25)	391 (18)	492 (19)
	DW	826 (56)	821 (56)	1,007 (60)	1,431 (75)	1,452 (75)	1,797 (82)	2,145 (81)
Pacific, Western Central	Local	2,360 (100)	2,500 (100)	2,700 (100)	2,890 (100)	3,280 (100)	3,440 (100)	3,900 (100)
	DW	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Pacific, Eastern Central	Local	498 (80)	497 (83)	560 (87)	680 (88)	663 (83)	645 (85)	738 (86)
	DW	122 (20)	103 (17)	80 (13)	90 (12)	137 (17)	115 (15)	122 (14)
Pacific, Southwest	Local	84 (56)	100 (62)	110 (58)	105 (62)	114 (60)	102 (51)	106 (56)
	DW	66 (44)	60 (38)	80 (42)	65 (38)	76 (40)	98 (49)	84 (44)
Pacific, Southeast	Local	10,399 (100)	8,260 (100)	10,148 (100)	11,171 (100)	11,852 (100)	10,240 (100)	13,694 (100)
	DW	15 (0)	12 (0)	17 (0)	11 (0)	20 (0)	26 (0)	18 (0)
World	Local	41,590 (90)	41,300 (88)	44,640 (88)	47,580 (88)	50,880 (89)	49,170 (89)	54,590 (88)
Total	DW	4,620 (10)	5,430 (12)	5,810 (12)	6,330 (12)	6,090 (11)	6,320 (11)	7,140 (12)

The less inclusive definition of distant-water fisheries has been used to include catches taken by countries without any coastline in the region concerned. The catches thus excluded, such as those of Italian vessels fishing off the North African coast of the Mediterranean, of United States shrimp vessels off South America, of Thai trawlers outside the Gulf of Thailand, or of some West African countries, are perhaps small compared with the total distant-water catch. The exceptions are the large catches taken by Japan, and to a lesser extent the USSR, in the northwest Pacific, some of which should be treated as distant-water fishing.

Table 1 indicates that in virtually all parts of the world distant-water fisheries account for a significant part of the catch, totalling some 12% by weight. The importance of this is greater than it seems because, with a few exceptions, the long-range fleets do not exploit the low value species, such as those used in bulk for fish meal, but do include many of high value. For example, the majority of tuna catches are taken by long-range vessels.

Table 2 sets out the contribution of distant-water fisheries to certain selected countries, both developed and developing. The table shows the great importance of such fisheries to several countries, as they provide half or more of the total catch. Clearly, without long-range operations these countries — especially those with limited resources around their coasts — would suffer a serious reduction in their supplies of fish. This pressure to engage in long-range fishing by countries with sufficient technical capacity and economic resources (which will include an increasing number of developing countries) but without adequate local fish resources, is likely to continue. Among other reasons, this is so because the major centers of fish consumption do not altogether coincide with major fish concentrations. This is perhaps most obvious, within a relatively small geographical area, off West Africa. The biggest populations, and the largest demands for fish, are along the northern coasts of the Gulf of Guinea, whereas the biggest stocks of fish are off the lightly populated coasts of Mauritania and Spanish Sahara. It is, therefore, not surprising that several of the countries bordering the Gulf of Guinea have, or are planning to organize, distant-water operations, and intend to join the European and other non-African countries with long-range fleets fishing in these waters.

Rational Use of Resources

Although long-range fishing is, at least in the short-term, essential to the wellbeing of the fisheries of several major countries, a wider view of their contribution to the rational utilization of the resources, taken as a whole, should also be considered. This depends largely on the degree of exploitation of the resource concerned. If it is light, then the advent of long-range fleets will increase the total catch, with minor unwelcome side-effects such as decreased catch per unit effort by other fisheries on the same stocks. Most long-range fisheries have developed on stocks of fish previously lightly exploited. Except where local fisheries have been restricted for management or other reasons, it is only in undeveloped areas that the density of fish and catch rates are high enough to attract long-range vessels.

The initial effect of long-range fishing is therefore toward a better utilization of the resource. This is clearly shown, for example, in Table 1 for the catches in the Southwest Atlantic, where fishing by local vessels on the Patagonian shelf has been, up to the present, relatively light. Local catches have been around 500–600 thousand tons, but the total catch jumped to over a million tons in 1967 when long-range vessels, principally from the USSR, took large quantities of hake. These vessels withdrew in 1968 for political reasons rather than because of any decline in stocks. A recent study by a working group of CARPAS stated that the increased catches had not had any serious effect on local catches of the major species (hake) (as can be seen in Table 1), which were well below the level of the maximum sustainable yield from the resource.

TABLE 2. The contribution in thousand tons and, in parentheses, percentage of total catch of local and long-range fisheries to the catches of certain selected countries.

	Year						
	1964	1965	1966	1967	1968	1969	1970
Cuba							
Total	37	41	44	65	66	79	105
Local	37 (100)	41 (100)	42 (98)	62 (95)	62 (94)	69 (87)	62 (59)
Long-range	– (0)	– (0)	1 (2)	3 (5)	4 (6)	10(13)	43 (41)
Japan							
Total	6232	6760	6961	7713	8515	8449	9147
Local	5390 (87)	5844 (86)	5870 (84)	6169 (80)	6814 (80)	6615 (78)	7135 (78)
Long-range	842 (13)	916 (14)	1091 (16)	1544 (20)	1701 (20)	1834 (22)	2012 (22)
Korea (Rep. of)							
Total	599	640	701	749	841	879	934
Local	598 (100)	638 (99)	692 (99)	733 (98)	815 (97)	831 (95)	881 (94)
Long-range	1 (+)	2 (+)	9 (1)	16 (2)	26 (3)	48 (5)	53 (7)
Poland							
Total	244	280	316	321	386	387	451
Local	193 (79)	199 (71)	201 (64)	154 (48)	153 (40)	165 (43)	204 (45)
Long-range	51 (21)	81 (29)	115 (36)	167 (52)	233 (60)	222 (57)	247 (55)
Spain							
Total	1200	1328	1351	1429	1503	1483	1483
Local	763 (64)	795 (60)	733 (54)	729 (51)	738 (49)	755 (51)	781 (53)
Long-range	437 (36)	533 (40)	619 (46)	700 (49)	765 (51)	728 (49)	702 (47)
USSR							
Total	3749	4273	4560	4959	5301	5752	6399
Local	2238 (60)	2414 (56)	2547 (56)	2624 (53)	3003 (57)	2992 (52)	3316 (52)
Long-range	1511 (40)	1859 (44)	2013 (44)	2335 (47)	2298 (43)	2760 (48)	3083 (48)

Once long-range fishing begins it is most unlikely to remain at a low level. The practical constraints of marketing and distribution, which often limit a local fishery, apply less to long-range fishing. If the resource provides rewarding catches, then vessels will be attracted to it until the point is reached at which declining stocks, and reduced catch rates, make opportunities elsewhere more attractive. Thus, in a long-distance fishery the stock will almost certainly become heavily exploited, and problems of management will arise.

MANAGEMENT PROBLEMS

In many ways the presence of long-range fleets introduces no new problems of management. So far as stocks are concerned, what matters is the rate at which fish are being caught (and sizes taken). It matters little whether they are caught by 1000 small boats or 20 large factory trawlers. Indeed it is simpler, if the total catch has reached twice the optimum level, to reduce it 50% by diverting 10 factory trawlers to other areas than to find alternative employment for 500 small vessels. Long-range fleets are usually run by relatively large enterprises (either state-controlled or privately owned), so that once steps for management have been clearly recognized, the practical and social difficulties of putting these into effect are less with such fleets than with the multitude of units involved in small-scale fisheries. Even when there are no possibilities of diversion, it is easier to persuade a company owning a fleet of trawlers to scrap some of its less efficient vessels, amounting to say 20% of capacity, and employ the crews among the rest of the fleet as vacancies occur, than it is to reduce the numbers of independent fishermen by 20%.

A distant-water fishery may well, however, increase the probability of excess fishing effort occurring, and the consequent need for management. The latter should be established and recognized before excess fishing reaches a serious level. It is sometimes thought that because countries with long-range fleets have less permanent and direct interests in fish stocks concerned, they are slower in admitting the need for management measures. Perhaps there is some truth in this, although countries with local fisheries have not been noticeably less short-sighted in adopting timely conservation measures. Some of the more spectacular failures in the latter case have been in fisheries under the control of a single country (e.g. the Californian sardine). The rapidly dwindling number of lightly exploited resources to which long-range fleets can be diverted means that, in their own interests, countries operating long-range fleets must take a more responsible attitude toward the management of such stocks.

A more substantial problem raised by long-range fleets is the rapid rate at which fishing on a particular stock increases. Traditionally, management measures have been introduced after careful scientific study of the effects of such measures (including, as an important special case, the effect of taking no action). These studies are usually based on analysis of the effects on the fish stocks, especially on relative abundance, as measured by the catch per unit effort. At best, several years are likely to pass between the time when fishing begins to have a measurable effect on the stock and the time when management measures are introduced. Unfortunately, in long-range fisheries developments are far faster. Typically, after an initial experimental period, catches build up within one or two years to a level beyond that which the stock can sustain. In this situation, the traditional pattern of introducing management measures is likely to result in action being "too little and too late."

The problem is not confined to long-range fisheries, because local fisheries can also develop fast when conditions are favorable, especially when they can sell their products to a large established market. Thus, the Peruvian anchoveta fishery built up from virtually nothing to near a peak of 10 million tons within less than a decade, and the Norwegian mackerel fishery, through diversion from the declining herring fishery, built up to a peak in only 3 years. A common example is shrimp fishing. Stocks of shrimp are local, and often small, but are wanted by a large worldwide market. Capital to develop a shrimp fishery is often easily available, so that a local fishery can build rapidly up to or beyond the optimum level.

EARLY ASSESSMENT

The management of such fisheries requires some change in the traditional procedures, but this should not be difficult. The chief need is a willingness to accept some degree of management action, possibly no more than a precautionary slowing down or pause in the rate of development, until there is scientific evidence of the extent of exploitation of the stock. Perhaps the approach should be somewhat more positive, such as permitting significant increases in fishing only if and when there is reasonable scientific evidence that the proposed catches will leave the resource viable. This implies the need for a certain minimum of scientific work preceding any large-scale development to obtain at least first-order estimates of the possible productivity of the stocks. These estimates, from research surveys, would provide preliminary targets for the development of the fishery, and can be adjusted as more numerous and more precise data are accumulated with growth of the fishery. Such estimates, of course, may be extremely useful for planning the rational development of the fishery as well as in guiding the first steps of management. They are as likely to be valuable in avoiding losses from failure to develop adequately a fishery on a productive stock as in preventing over exploitation of a limited resource.

Given these developments — early collection and analysis of scientific data, including survey or other activities in advance of any large-scale commercial fishing, and willingness to take appropriate precautionary action even when scientific evidence is incomplete — there is no compelling reason why fish stocks exploited by long-range fleets should not be as successfully managed as those exploited solely by local vessels.

Successful management from the resource point of view does not mean that all problems are solved. Successful management in general should give results acceptable to all participants, whereas a management program could be highly successful so far as the resource is concerned yet involve severe losses to some section of the fishery. Incidentally, some complaints against long-range fishing have been concerned less with the possible harm done to the resource than with the adverse effects on the local fishery.

Effect of Long-Range Fleets on Local Fisheries

The effects of long-range fishing on fisheries in the same area are not necessarily harmful. Often two fleets are fishing different species and their interaction is not great. There may be physical interference, such as between trawlers and lobster vessels on Georges Bank but, provided there is a willingness to accept reasonable rules of behavior, these do not seriously threaten the livelihood of the local fishermen. The interference is not different in kind from that which can occur between local fleets, e.g. between local African trawlers and canoes using gillnets.

There may be interactions between the fisheries at the biological level even when the species caught are different. For instance, the long-range fleet may harvest a species that is a predator on, or competes with, the fish caught by the local fishery, in which case the effect is likely to be beneficial. A somewhat similar beneficial effect appears to have occurred off the northwestern coast of the USA. Here the long-range fleets mainly exploit species such as hake or rockfish which are generally of minor importance to the local fisheries. Apparently, though the biological evidence is not conclusive, the trash fish and other waste discarded from the large trawlers have resulted in a considerable increase in the numbers of Dungeness crab, to the delight of the local fishermen.

The degree of separation between species caught by the two groups of vessels is seldom complete, and an important problem arises when a large long-range fleet takes, incidentally to its operations on some abundant stock, quantities of a less abundant species which supports a local fishery. For example, the long-range fleets in the Northeast Pacific catch numbers of halibut, which support an important local fishery. Although a small fraction of the take of the long-range vessels, these catches interfere seriously with the long-established and highly successful (at least in the biological sense) program of management of the halibut fishery. This interference is especially severe because the mesh size of the nets used by the large trawlers for other species of fish involves the capture of halibut below the optimum size for best management.

The resolution of this halibut problem — assuming there is no technological solution, whereby the trawlers can harvest other species effectively without catching small halibut — must lie in balancing the special interests of the halibut fishermen and the wider interests of making the best use of the much larger (particularly in weight) resources of the other bottom-living species. This is a general problem and is not a special problem of conflict between long-range and local vessels.

The biggest theoretical conflict arises from the extent to which a long-range fishery, even when harvesting no more than the sustainable yield from a resource, can inhibit the development of a local fishery on the same resource. Even if the fishery is being properly managed and productivity of the stock is high, the standing stock will be less than if long-range fleets were not operating. The resultant lower catch rates might make the development of a new local fishery more difficult. However, it is unusual for the efficiency of a given vessel to remain constant as a fishery develops. Initially, before the fishermen have learnt the best times and places to fish and the best type of gear to use, catches tend to be low. They tend to increase as knowledge and experience grow, and this increase at first often more than balances the decrease due to reduction in the stock.

Thus the catch rates of local vessels once they are experienced, even when the long-distance vessels are operating, may well be at least as high as that of inexperienced local vessels fishing on an unexploited stock. The difficult period is that when local fisheries are gaining experience in a fishery already exploited by long-distance fleets. This learning process can be shortened and improved by the actual operation of the long-range fleets.

In this way the fleets can be of positive help to the development of a local fishery. Also their presence provides conclusive proof to possible investors, government or private, of the existence of the resource and of the scale of probable catches from it. An example of these effects is provided by the fisheries of West Africa. Among the first to exploit the offshore demersal resources were trawlers from USSR, Poland, and other countries; these put into local ports for supplies and, to pay for these supplies, landed a percentage of their catch. These fish were so highly acceptable in local markets that some long-range vessels began to fish specifically for them. Then vessels were chartered by local governments or private enterprise, as an interim step to building up their own fleet of offshore trawlers.

The other aspect is the degree to which local and long-range boats can co-exist, or whether the greater efficiency of one fleet can drive out the other, even when stocks are not being too heavily exploited. A distinction should be made between differences in efficiency of the two types of fishing, and the fact that long-range fleets are likely to be technically advanced compared with boats of the local fishermen. Where the local fisheries are technically backward, they can certainly suffer as in parts of the Northwest Atlantic. On the other hand, as already noted, the same fleets of European long-range vessels cannot compete with highly efficient local vessels in the Northeast Atlantic.

Long-range vessels incur high costs involved in maintaining ships and crews at sea a long way from home base. The costs of operating processing plants on board ship, including direct (wages) and indirect (accommodation, etc.) labor costs, may well be twice or more the costs of operating equivalent plants on shore. These costs will often more than offset the technological advantages of long-range fleets and their ready access to good markets. In time, both these can be attained by local fleets.

The great permanent advantage of long-range fleets is their flexibility. Many fish stocks undergo considerable natural variation, both in actual abundance (e.g. year-class fluctuations) or in availability (e.g. concentration in part of the area by unusual hydrographic conditions). Such variations are generally bad for local fleets. They suffer considerably under poor conditions but cannot, because of limited capacity, take full advantage of good conditions. Long-range fleets can easily switch from stock to stock of the same or different species to concentrate where conditions are particularly favorable. Opportunities to do this are greatest when, as in the North Atlantic distant-water cod fisheries, a number of independent stocks, which are unlikely to fluctuate together, support what is essentially a single fishery. In such cases, but probably in few others, long-range fleets may be able to compete with local vessels even in the long-term.

Conclusion

Long-range fleets have initiated acrimonious discussions in international fishery affairs. Their activities have initiated or increased many difficult problems of fishery development and management. However, they have tended to increase the degree to which fish resources of the world are fully and properly utilized. From the development of the cod fishery off Newfoundland some centuries ago (which, because of the use of shore facilities, was a mixture of local and long-range fishery), to the recent development of major trawl fisheries in the Bering Sea, the Northeast Pacific, and elsewhere, long-range fleets have led the way in large-scale utilization of many major fish stocks. If such fishing stopped tomorrow, there would certainly be a substantial and prolonged drop in the total world fish catch.

Although the rapidity with which long-range fleets can build up their catches raises increasingly urgent problems of management, these problems are no different in kind from those arising in all parts of the world as fishing intensifies. Regardless of the type of operation involved, more positive steps are needed to ensure the timely introduction of management measures and rational development of the fisheries.

Conflicts and competition between local and long-range fleets appear at present to be weighted in favor of the big boats and, by implication, against the smaller or developing countries. Though the latter do have disadvantages, these may be overcome by the normal processes of development, rather than requiring special measures. The current advantages long-range fleets often have are access to modern technological and other expertise (better business management may well be an important factor) and access to larger and better markets. As far as developing countries are concerned, programs of assistance, both bilateral and multilateral, may be expected to tackle the first problem, and the growing general demand for fish throughout the world will tend to improve marketing opportunities for local fisheries. Also, one may expect some commercial enterprises operating long-range fleets to find it more profitable (and possibly politically more acceptable) to obtain their supplies of fish by investing in local fisheries. As these changes take place, one can expect a general phasing-out of the large long-range fleets and their replacement by efficient local vessels, which have benefitted from the experience of the other fleets.

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Ghana's Experience in Distant-Water Fisheries[1]

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ADJETEY, J. N. N. 1973. Ghana's experience in distant-water fisheries. J. Fish. Res. Board Can. 30: 2463–2467.

Ghana's investment in a modern fishing industry includes fishing vessels of various ranges and sizes, costing over £25.6 million. There have also been heavy investments in infrastructure, such as the Tema fishing harbor, boatbuilding, cold storage, and repair and maintenance facilities. These investments were made to: improve the protein content of the Ghanaian diet; stop importation of frozen fish and fishery products; develop the skills of the fishing community; develop an export trade in fish.

Efficient use of these investments has been hampered by various factors. Transition from a canoe to a sophisticated fishery of refrigerated trawlers and factory ships was too rapid. It was assumed that once the fishing industry was equipped with a modern fleet it would become self-supporting within a short time. But this was not the case because realization of this goal depended on: efficiency with which the fleet was operated, better handling and care of fish, better marketing and distribution methods, search for new grounds, and constant attention to conservation of stocks.

Lack of finance made operation of the fleet difficult. Spare parts were not in adequate supply and at times vessels had to stop fishing for lack of them.

Lack of local personnel led to dependence on alien captains, mates, engineers, and shore-based staff. The number of alien crew was high initially, but Ghanaians have gradually taken over key positions on the vessels.

Ghana is the only West African state with a fleet of deep-sea trawlers. This situation and recent unilateral extensions of fishing limits by West African states have led to a new problem which might have far-reaching effects on the operation of the fleet.

But Ghana's attempt to participate in the exploitation and utilization of West African fishery resources should encourage other African states to similar efforts.

Les investissements du Ghana dans l'industrie halieutique moderne portent, entre autres, de navires de pêche à rayon d'action et de dimensions variables, représentant plus de 25,6 millions de livres sterling. Le Ghana a aussi fortement investi dans l'infrastructure, port de pêche de Tema, chantiers navals, entrepôts frigorifiques et installations de réparation et entretien. Ces investissements visent à: améliorer la teneur en protéines du régime ghanéen; mettre un terme aux importations de poisson et produits de la pêche congelés; développer les compétences des collectivités de pêcheurs; favoriser les exportations de poisson.

Divers facteurs ont fait obstacle à l'utilisation efficace de ces investissements. Le passage de la pêche à la pirogue à la pêche moderne avec des chalutiers dotés d'installations frigorifiques et des navires-usines a été trop rapide. On avait pensé qu'une fois équipée d'une flottille moderne, l'industrie de la pêche deviendrait autonome en peu de temps. Mais il n'en a pas été ainsi, car la réalisation de ce but dépendait de divers éléments: efficacité de l'utilisation de la flottille, meilleure manutention du poisson, amélioration des méthodes de commercialisation et de distribution, recherche de nouvelles zones de pêche et souci constant de la conservation des stocks.

Le manque d'argent a rendu difficile l'utilisation de la flottille. L'approvisionnement en pièces de rechange a laissé à désirer et, faute de ces pièces, des navires ont dû interrompre leurs opérations de pêche de temps en temps.

Le manque de personnel local a conduit le pays à s'en remettre à des patrons, des contremaîtres, des mécaniciens et du personnel à terre provenant de pays étrangers. Le nombre d'équipages étrangers a été élevé au début, mais des Ghanéens les ont progressivement remplacés dans des postes-clés à bord des navires.

Le Ghana est le seul etat ouest-africain possédant une flottille de chalutiers de haute mer. Cette situation et la décision récente prise unilatéralement par les etats ouest-africains de repousser les limites de pêche soulèvent un nouveau problème qui risque d'avoir de sérieuses répercussions sur les opérations de la flottille.

L'effort déployé par le Ghana pour participer à l'exploitation et à l'utilisation des ressources halieutiques de l'Afrique de l'Ouest devrait néanmoins encourager les autres etats africains à suivre son exemple.

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Gran parte de las inversiones de Ghana para crear una industria pesquera moderna se destinó a barcos de pesca de varios tipos y tamaños, por un costo de más de 25,6 millones de libras. Se han realizado también grandes inversiones en infraestructure (como el puerto pesquero de Tema), construcción naval, frigoríficos e instalaciones de reparación y manutención. El objeto de estas inversiones ha sido: mejorar el contenido proteínico de la alimentación de los ghaneses; frenar las importaciones de pescado congelado y productos pesqueros; mejorar los talentos de la comunidad pesquera; fomentar la exportación de pescado.

El aprovechamiento eficaz de estas inversiones se ha visto obstaculizado por varios factores. La transición de la pesca con canoa a una pesquería más moderna de arrastreros refrigerados y buques factoría ha sido demasiado rápida. Se partió de la base de que una vez que la industria pesquera contara con una flota moderna, conseguiría ser autosuficiente en breve plazo. Pero no sucedió así, porque ese resultado depende de la eficiencia con la que se administra la flota, de la mejora de la manipulación del pescado y de los métodos de mercadeo y distribución, de la búsqueda de nuevos caladeros y de la constante atención a la conservación de las poblaciones.

La falta de financiación hizo difícil el funcionamiento de la flota. Los repuestos escaseaban y eso obligaba a las embarcaciones a interrumpir la pesca.

Hay que mencionar la falta de personal local, que obligó a la industria pesquera a depender de capitanes, marineros, maquinistas y personal de tierra extranjeros. Los tripulantes extranjeros eran inicialmente muy numerosos, pero los ghaneses han ido sustituyéndolos gradualmente en algunos de los puertos claves a bordo.

Ghana es el único estado del Africa occidental que cuenta con una flota de arrastreros de altura. Esta situación, y la receinte ampliación de los límites de pesca de algunos estados del oeste de Africa, han planteado un nuevo problema que podría tener enormes consequencias para el funcionamiento de la flota.

De todas formas, el esfuerzo de Ghana por participar en la explotación y aprovechamiento de los recursos pesqueros del Africa occidental debe alentar a otros estados africanos a hacer lo mismo.

IN recent times most developing nations have striven to increase food production to meet the high rate of population growth. Ghana's launching of "Operation Feed Yourself Campaign" was geared to meet this demand and to stimulate food production, thus reducing the country's dependence on food imports. The importance of this is illustrated by the fact that the Government of Ghana spent over £62 million (sterling) on various food items and agricultural raw materials in 1970.

As fish provides much-needed protein, it is logical for these countries to turn to the sea for fish and make it available to all sections of the population, thus arresting the threat of malnutrition. With the exception of a few pelagic species, the main centers of marine fisheries are located on the continental shelf. As Ghana has a rather narrow continental shelf, it was decided to develop a long-range fishing fleet to operate on the high seas as has been the practice of developed nations.

The fishing industry of Ghana has undergone spectacular changes over the past 15 years, with rapid growth in size and number of vessels, as well as in landings. For the deep-sea fleet this rapid expansion took place between 1963 and 1965, during which 20 trawlers were delivered. There are several reasons for this expansion: there is the importance of fish in the Ghanaian diet; Ghanaians have long been known to be good fishermen, operating in canoes along the whole of the west coast of Africa; the Government wanted to increase the quantity of protein available to the population, to improve living standards; and finally, Ghanaians are efficient in the use of motor fishing vessels, which has promoted establishment of a thriving boatbuilding industry for inshore vessels.

Another stimulus to development of a deep-sea fleet was that the developed nations were fishing heavily in nearby waters and selling their catch to Ghana. A State Fishing Corporation was established in 1961 and charged with the responsibility of operating the fleet.

The Traditional Fishing Industry

Before discussing the deep-sea fleet, let us consider the traditional fishery prior to introduction of powered craft. The canoe, which has been described by naval architects as being of perfect design in its own right, has been the craft traditionally used for fishing. Its size varies from 25 to 40 ft overall, with a beam of up to 4 ft and an inside depth of 3–4 ft. It carries a crew of 5–15 men. It is normally operated with paddles but also uses sails. Traditional gear includes various types of nets, such as the cast net, the "ali" net (a gillnet), bottom and floating setnets, and modified lampara nets. The most important fish exploited by the canoe fleet have been the *Sardinella aurita*, which enter the harvesting range of the canoe during July to October. These fish are caught in 20–40 m of water and landings from canoes have contributed about 60% of the total marine catch. In addition, *Scomber japonicus* and *Decapturus rhonchus* are now becoming big items in the catch.

Interest in this traditional fishery began when some studies into fish smoking methods were undertaken by a Government chemist in 1941. This work was carried out in conjunction with the Prisons Department, which had built some ovens at Keta. The Department also had a few canoes and operated with the "ali" and beach-seine nets.

Increasing attention has been paid to the canoe fisheries, which are likely to remain the biggest supplier of fish in Ghana for some time to come. Ways of improving traditional vocation and life are being explored, such as mechanization of the canoes and the introduction of improved gear. For example, there is a scheme for providing outboard engines for canoes. As some 70,000 people are directly concerned with the canoe fisheries, their importance socially, economically, and from the viewpoint of landings, is clear.

The foundations of a separate organization to handle fisheries matters were laid in 1945 by setting up the Osu Fisheries Station. This small unit concerned itself with improvement of local methods of fishing, suitability of *Sardinella aurita* for canning and fish-meal, experiments with different types of fishing nets, and collection of statistical data for marine and inland fisheries.

The Government had become aware of the need for more protein in the diet, and decided to increase fish production. It was found necessary to import some motor fishing vessels, the first of which was brought from Britain in 1946 and used for fishing herring by driftnets. The vessel was 14 m overall with a 15 hp engine. Its introduction met with opposition from local fishermen but, with education and demonstration, some fishermen became interested and 2 years later a second vessel of the same specifications was imported. Later, the driftnet was replaced by a modified Granton trawl which became popular with the fishermen.

The Department of Fisheries was established in April 1949. By 1952, the demand for motor fishing vessels had become so insistent that a boatbuilding yard was established, and in March 1953 the first 14-m locally built vessel, named *Corona*, was launched for the Department. Since then, boatbuilding has become an important aspect of the fishery development program and no fewer than 400 inshore fishing vessels have been built locally.

With the increasing fleet of fishing vessels the need for safe anchorage became evident, and the Government established a fishing harbor with facilities such as a fish market, cold storage, ice-making plant, and repair and maintenance service. Fishery schools, giving training in elementary seamanship and navigation and in repair and maintenance, were also established.

The Deep-Sea Fishery

The Government's eagerness to develop a long-range fleet culminated in six contracts with overseas shipbuilders for vessels that cost approximately £15.6 million. In addition, there were investments in ports, cold-storage facilities, and other shore installations.

The first contract was signed in March 1961 with Seaworks Ltd. of Britain for six vessels having an overall length of 127 ft (58 m). Two were stern trawlers and four were tuna purse-seiners; the former cost £160,000 each and the latter £162,500 each. Soon after delivery of two purse-seiners minor defects were detected in the auxiliary engines, and 2 months later the engines broke down completely; one engine had a broken crankshaft and damaged connecting rods and pistons. The unsuccessful operation of these two vessels was attributed to the age of the auxiliary engines, which were reconditioned war surplus stock and at least 10 years older than the vessels. The Government decided to get rid of all these boats and they were sold for £479,830 — a loss of £470,369. By this time Ocean Fisheries Limited, a Ghanaian company, in conjunction with a Japanese firm was operating one deep-sea trawler and one carrier vessel.

The second contract was signed in August 1961 with V/O *Sudoimport* of the Soviet Union for 10 173-ft (78 m) overall side trawlers at £167,000 each. These vessels were abandoned when the Russian crew members left the country in February 1966.

The third contract was signed with Mr Akers Verksted of Oslo, Norway, in June 1963, for six 214-ft (97 m) overall stern trawlers at £590,000 each. A seventh vessel, which had been ordered by a Ghanaian company, was taken over by the Government in November 1964. All seven vessels were delivered and are operated by an Akers management team under an agreement with the Government. They had previously been operated by the State Fishing Corporation with little success.

The fourth contract for vessels was signed in August 1963 with the Mitsui Shipbuilding and Engineering Company Ltd. of Japan for 12 vessels, comprising five 254-ft (115 m) overall stern trawlers at £545,000 each, five 219-ft (99 m) overall stern trawlers at £465,000 each, and two 211-ft (96 m) overall carriers at £325,000 each. The first five stern trawlers and the two carriers have been delivered and are operating satisfactorily. The other trawlers have not been delivered.

The fifth contract was signed in February 1964 with the Newport Shipbuilding and Engineering Co. Ltd. of Britain for six 347-ft (157 m) overall trawlers, each costing £599,083. Five vessels have been delivered and are being operated by the State Fishing Corporation. Their performance calls for much improvement.

The sixth contract was signed March 18, 1965 with Messrs Brodoimpeks of Yugoslavia for 12 75-ft (34 m) overall inshore fishing vessels costing £45,710 each. Three of these have been delivered. One is being used by the Fisheries Department for research work, the others have been sold to Ghanaian fishing companies. Experience gained from the operation of the three vessels made it necessary for the Government to advise the shipbuilders on modifications for the remaining nine vessels. To keep the price at the contract figure, six modified vessels are to be built in place of the nine ordered.

In addition to the Government's operation of deep-sea fishing vessels, Ghanaian companies participating in deep-sea fishing include Mankoadze Fisheries Ltd. and Ocean Fisheries Ltd; the former is operating seven vessels and the latter three. It is estimated that these companies and small boat operators have invested a total of £10 million in fishing vessels.

The rapid growth of the fishing industry, particularly in connection with the deep-sea trawlers, has been associated with a number of problems. For example, at times some of the vessels have been idle for lack of crews or lack of spares, and so on. Indeed, expansion had been so rapid that a period of consolidatoin was required for development of management and other skills for operation of the vessels.

Fish Production

The present level of fish production from marine sources is about 180,000 metric tons. Estimated production from the deep-sea vessels could be higher. For instance, the State Fishing Corporation's ten deep-sea trawlers produced 27,138 metric tons of fish in 1970 whereas, at optimum level of operations, i.e. five trips a year, landings should have been 33,000 tons. Similarly, Mankoadze Fisheries Ltd., which operated seven vessels during the same period, produced 13,874 metric tons instead of 24,130 metric tons. Ocean Fisheries Ltd., with three vessels, landed 6,230 metric tons instead of 11,520 metric tons. The total production of the deep-sea fleet was therefore 47,242 metric tons. During the same period, 357 medium-size and inshore vessels produced 20,192 metric tons of fish instead of 47,800 metric tons. Of 425 vessels in this group, 68 were not in operation. The canoe fisheries continue to make a substantial contribution, having landed 90,000 metric tons in 1970.

It looks as if there are trawlers enough to meet the country's fish requirements, if efficiently operated, as fish landings from the 384 vessels should be about 560,000 metric tons.

Figures for 1971 were not much different from those for 1970. In fact, the State Fishing Corporation landed 22,540 metric tons of fish, which was less than its 1970 production, while operating the same number of vessels. Mankoadze Fisheries Ltd. produced 19,220 metric tons, while Ocean Fisheries Ltd. landed 7060 metric tons.

The total annual catch of fish from 1963 to 1971 and the growth of the deep-sea fleet is shown in the following table:

Year	Catch in metric tons	No. of vessels
1963	7,932.4	6
1964	12,002.8	13
1965	30,311.3	20
1966	25,299.0	36
1967	27,546.5	17
1968	23,019.0	29
1969	37,096.8	29
1970	47,438.3	23
1971	48,820.9	23

Although smaller side trawlers as well as larger stern trawlers sometimes fish off the coast of Ghana, the bulk of the landings are caught off the coasts of other African nations, particularly off Mauritania, Spanish Sahara, and Senegal, and recently off Angola. Unilateral extension of fishing limits by neighboring states has posed a difficult new problem. Even before these extensions, however, Ghanaian deep-sea vessels have on a few occasions been arrested for poaching and heavily fined.

My assessment of the situation is that the idea of an African state with a deep-sea fleet is not readily acceptable, because hitherto only the fleets of developed nations have operated in distant waters. This attitude and the fact that the Ghanaian vessels have alien personnel aboard make it difficult for other African states to appreciate that a country like Ghana could operate such a fleet. The question usually asked is whether the vessels really belong to Ghana. It has also been suggested that the Ghanaian companies operating the vessels are acting as a front for foreign firms which are the real owners. However, it is being gradually accepted that Ghana in fact owns the vessels as there are now many Ghanaian personnel on them.

Problems of Operating a Deep-Sea Fleet

For a developing country like Ghana, operation of a fleet of deep-sea trawlers presents problems. Although aimed at reducing Ghana's expenditure on fish imports, operation of the fleet made heavier demands on the country's foreign exchange earnings than had been envisaged. In this respect one cannot run away from the fact that a main difficulty preventing the efficient operation and administration of the deep-sea fleet has been inadequate financial support.

Apart from buying the vessels, expenditures for spare parts, fishing gear, and various other equipment are all in foreign currency. This could be offset by establishing an export trade in tuna and shrimp, but such an enterprise needs to be developed. It can also be said that not much assistance has been forthcoming from developed nations based in, or having licences to fish in, Ghana's territorial waters. And finance, of course, is vital to the successful operation of the vessels because any failure to meet commitments can immediately halt operations.

Apart from being able to make payments in foreign exchange, there is the need to have adequate local currency. Operational subsidies, especially during the herring season between July and October each year, will help alleviate some of the financial problems. During this period, when there is a glut of fresh fish on the market and sales of frozen fish come almost to a halt, short-term operational subsidies can help keep the trawlers at sea when prices become unattractive. Another financial aspect relates to availability of credit from institutions; when credit has been available, interest rates have been high.

As trained local personnel were not available to take up key positions on the vessels, a number of aliens had to be recruited. Initially, each vessel carried 15–40 aliens, which the captains insisted on having as they considered Ghanaian crews were not competent — even as stewards, cooks, and greasers. It became evident that some alien personnel were more interested in finding employment than in training Ghanaian crews, and although such training has always been stressed in agreements, foreign companies have only paid lip service to this commitment. It is also worth mentioning that while Ghanaian deep-sea vessels were not being operated efficiently by alien crews, the countries from which the vessels and crews had come were efficiently operating their own vessels in West African waters and selling the catch to Ghana. This situation actually undermined the efficiency of our vessels.

Salaries paid to alien crews were high and constituted a big drain on financial resources, as part of the salaries had to be paid in the home currency of the aliens. In addition the crews claimed a bonus on the quantity of fish landed; unfortunately this had no relation to quality of the fish. If there were delays in port, crews claimed loss of fishing time and received compensation — in effect, a bonus for fish they had neither caught nor landed. Such demands by these crews gave the impression that they were not interested in the viability of the project as a whole. This did not apply to all crews, and some were concerned about the quality of fish landed.

It was also not easy for alien captains to recommend the replacement of staff by trained Ghanaians. Even when Ghanaians had the requisite training and experience, alien personnel handed over their duties with great reluctance. However, every effort has been made to reduce the number of aliens and the majority of the vessels now carry no more than five — the captain, chief mate, chief engineer, first engineer, and trawlmaster. The remaining positions are taken by Ghanaians.

While aliens still make up 40% of the 500 officers of the deep-sea fleet, training of Ghanaians to take over these sea-going jobs is being actively pursued. In addition to the training schools already mentioned and the training of cadets abroad, the Ghana Nautical College has set up an engineering workshop, built with assistance from the Norwegian Agency for International Development, for training engineers.

Another factor which has contributed to poor efficiency of the fleet has been the lack of carriers to work in conjunction with the catchers. This was particularly the case with the Russian-built trawlers which, with a fish hold capacity of 120 tons and freezing capacity of 6 tons of fish per 24 hr, needed carriers to make operations viable in fishing on such distant grounds. This should have been realized at the time the contracts for the vessels were negotiated. Later, in fact, two carriers were included in the Japanese contract.

I have already referred to the fact that we took delivery of 20 vessels between 1963 and 1965. In fact, 24 should have been delivered in that period, but delays in making payments postponed delivery. This was clearly an example of insufficiently planned development, the financial aspect not being thoroughly evaluated. Indeed, the rate at which vessels arrived disrupted the plan for gradual transition from canoe fishing to use of motor fishing vessels and to refrigerated trawlers. The rate of delivery also had no relation to crew requirements and trained personnel to manage the whole operation. Again, it did not mesh with development of shore facilities such as workshops, maintenance and repair services, transport, storage, distribution, and marketing. Thus, during the herring season the deep-sea trawlers could not discharge their cargo for lack of storage space.

Conclusion

To sum up, while the Ghanaian effort to move from a traditional coastal fishery quickly into a modern, complex distant-water fishery operation has been a stimulating experience, some painful lessons have been learned. As already pointed out, the pace set for transition was too rapid. As a result, there was not sufficient time to carry out in detail all the essentials of a fishery development plan phased over a term of years. And it was because of these various adverse factors that, for example, the difficulties over foreign exchange were exacerbated, including the high cost of alien staff employed at all levels in the operation.

In the light of experience, the pace of development obviously should have been much slower and the whole question of operation of a distant-water fleet explored with a smaller number of vessels as a start. Such an approach would not only have permitted time to identify the problems of operating such vessels in the conditions and environment of West Africa, but would have provided the time required for training manpower and building up all the supporting services and infrastructure essential for efficient modern fishing fleet operations.

Expansion of Korean High-Seas Fisheries[1]

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AHN, M. N. 1973. Expansion of Korean high-seas fisheries. J. Fish. Res. Board Can. 30: 2468–2470.

Korea's high-seas fishery began in 1957 with a single tuna longliner. By 1971 it had increased to 351 vessels totalling 108,900 gross tons. Of these 291 are tuna vessels, the remainder fish for groundfishes, shrimps, etc. The total of 159,000 tons of product taken in 1971 was divided fairly evenly between tuna and groundfishes, but of course the tunas were much the more valuable.

The high-seas fishery industry is encouraged by government assistance in financing, vessel construction, personnel training programs, marketing arrangements, fishery survey programs, and cooperation with international organizations.

Continued expansion of high-seas fishing is expected through 1976 at least. For example, 282 additional or replacement vessels are being planned for 1972–76. Skipjack tuna are a prime target for expansion, and the bait required in harvesting this species is available in Korean waters.

La Corée s'est lancée dans la pêche hauturière en 1957, avec un seul thonier palangrier. En 1971, sa flottille comptait 351 bâtiments totalisant 108,900 tonneaux de jauge brute. Il s'agit de 291 thoniers, tandis que le reste pêche les poissons de fond, les crevettes, etc. Le volume total (159,000 tonnes) de la production en 1971 était réparti assez équitablement entre les thons et les poissons de fond, les premiers présentant naturellement une valeur bien plus considérable.

Le Gouvernement encourage l'industrie de la pêche hauturière en accordant une aide financière pour la construction navale, les programmes de formation du personnel, les accords commerciaux, les programmes de prospection halieutique et en assurant la coopération avec les organisations internationales.

On pense que cette expansion de la pêche hauturière se poursuivra au moins jusqu'en 1976. On prévoit notamment 282 bateaux supplémentaires ou de remplacement pour la période 1972–76. L'un des objectifs prioritaires d'expansion est la bonite à ventre rayé, pour laquelle l'appât nécessaire existe dans les eaux coréennes.

En Corea, la pesca de altura se inició en 1957 con un solo palangrero. Para 1971 había 351 embarcaciones con 108,900 toneladas brutos. De ese total, 291 son atuneros, y el resto pesca especies demersales, camarones, etc. En 1971 las 159,000 toneladas obtenidas se dividieron con bastante igualdad entre atunes y especies demersales, siendo los primeros de mucho más valor.

El Gobierno fomenta la industria pesquera de altura mediante la financiación, construcción de barcos, programas de capacitación del personal, disposiciones sobre mercadeo, programas de estudios ícticos y cooperación con las organizaciones internacionales.

Es de esperar quí, por lo menos hasta 1976, continúe la expansión de la pesca de altura. Por ejemplo, para 1972–76 se intenta sustituir o adicionar 282 barcos. El principal objetivo de la expansión es la pesca del barrilete, existiendo en aguas de Corea el cebo adecuado para capturar esta especie.

Brief History of the High-Seas Fisheries of Korea

HIGH-SEAS fisheries were undertaken in Korea for the first time in 1957 when a tuna longliner of 229 gross tons made a trial cruise to the waters near Nicobar Island in the Indian Ocean. In 1958 fishing operations were carried out with increasing intensity in American Samoa. Four cruises were made there and this led to the establishment of a Korean commercial fishery on a sound basis. Since then a rapid development in the field of fisheries has been made, and the present industrial level has been achieved with encouragement and support given by Government policy, together with heavy investments by private concerns.

The Government planned the purchase of seven tuna longliners in the first year of its first 5-year Economic Development Plan which started in 1962, and provided part of the funds required. In 1963 this was increased to 10 longliners.

At the same time, private loan projects for the procurement of fishing vessels were successfully implemented and a total of 65 tuna longliners had been made available for fishing operations by December 1965.

To facilitate further development of deep-sea fisheries, a fishery loan agreement was formulated between a French–Italian consortium and the Government agency

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

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in 1962. With this loan, a total of 33.8 million dollars were made available in 1963 for 91 deep-sea fishing vessels with a total of 22,724 gross tons.

The Korean Marine Industrial Development Corporation was established in order to achieve proper management and operation of the fishing boats procured by the loan. The deep-sea fishing vessels delivered under the contract are actively engaged in the Pacific, the Indian, and the Atlantic oceans.

Korean deep-sea fisheries, which started with experimental fishing in 1957, have developed rapidly. There are now 351 vessels (108,850 gross tons) operating on the oceans of the world; they provided exports of 55 million dollars from a total catch of 159,300 metric tons in 1971. Fishery statistics for deep-sea fisheries, by year, are shown in Table 1.

Status of High-Seas Fisheries

A review of the figures shows an increase in 1971 of 77.7% in production and 46.4% in export value over those for 1970. Such growth was due to major improvements in fishing efficiency, to price increases in fishery products, and partly to the addition of 73 fishing units.

By area, the Pacific Ocean contributed 61.8%, the Atlantic Ocean 27.7%, and the Indian Ocean 10.5% (Table 2).

In 1971, 14 foreign fishing bases were used by the Korean deep-sea fishing fleet. These are Samoa, Fiji, and Santo in the Pacific area; Freetown, Tema, São Vicente, Monrovia, St. Martin, Las Palmas, and Abidjan in the Atlantic area; and Penang, Durban, Port Luis, and Tamatave in the Indian Ocean.

The size of deep-sea fishing vessels in Korea ranges from 100 to 3000 gross tons. The breakdown of the 1971 fishing fleet by gross ton classes shows that 68.1% of the fleet was of the 100–300 ton class, 29.6% was in the 200–400 ton class, and 2.3% were over 1000 tons. There is a tendency in the deep-sea fishing fleet to increase the average tonnage per boat. For example, in 1962 the average tonnage was only 120 gross tons; by 1971 average had increased to 310 gross tons.

Prospects for the Expansion of High-Seas Fisheries

As part of the nation's social and economic development plan, the Government will emphasize development of deep-sea fisheries during the 1970s.

An important contribution of the industry to the national economy is the continuing increase in foreign exchange earnings. Perhaps an equally important contribution made by this developing industry is in providing employment to those both directly and indirectly involved in fisheries. This rapidly developing inductry has stimulated the growth of facilities for vessel construction, repair shops, fishing gear, and marine electronics.

TABLE 1. Fishing fleet and catches, 1962–1971.

Year	No. of vessels	Catch (*metric tons*)	Index (%)	Export value ($1000)	Vessel tonnage
1962	5	657	100	209	600
1965	65	8,563	1,303	2,554	10,800
1966	138	26,852	4,100	9,183	29,200
1967	180	40,484	6,200	12,582	41,200
1968	210	50,074	7,600	15,559	60,200
1969	224	82,782	12,600	24,072	70,400
1970	278	89,621	13,600	37,663	75,800
1971	351	159,307	24,300	55,103	108,900

TABLE 2. Catches in 1971, by fishing area and by species.

Fishing area	No. of fishermen	Species	No. of boats	Catch (*metric tons*)
Pacific area	4321		160	98,638
		Tuna	122	29,856
		Groundfish	33	68,582
		Others	5	–
Atlantic area	3479		139	44,083
		Tuna	117	37,142
		Groundfish	20	6,941
		Others	2	–
Indian area	1393		52	16,786
Grand total	9103		351	159,307

Apart from aquaculture, there is little reason to believe that increased fishing effort will significantly increase total yield in waters adjacent to Korea. Hence, in view of the abundance of technicians and other manpower who are willing to work at sea, it is inevitable that Korean fisheries should expand to overseas fishing grounds.

It is generally conceded that the greatest potential for increased yields lies in the exploitation of skipjack tuna in the mid-western Pacific, not far from the Korean Peninsula. The present tuna industry in Korea is based entirely on the longline method of catching deep-swimming tuna. Skipjack, on the other hand, are surface tunas, the catching of which requires an abundant supply of live bait. Stocks of suitable bait are abundant in Korea, and the Government, through one of its development corporations, and also foreign interests, are planning to enter this fishery.

For the successful implementation of deep-sea fisheries development, the assurance of a firm position in international fisheries is of importance, in light of the fact that a deep-sea fishery is able to earn foreign currencies and can make a great contribution toward bolstering employment.

There are, however, many difficult problems facing the expansion of deep-sea fisheries in Korea, such as lack of capital, a local supply of manufactured products necessary for the operation of the fishing fleet, innovation of new fishing technology, improvement of the distributing system, training of fishermen, and research activity in the ocean, etc.

If the Government continues to extend valuable assistance to deep-sea fisheries and to its research activities, this industry will grow on a sound scientific basis. The basic measures for solving the above problems are as follows:

Replacement of Fishing Vessels

It is necessary to replace old fishing vessels with new ones in order to rationalize their management, to enhance catch per unit effort, and to secure new fishing vessels for the diversification of fishing activities. The Government program for the domestic construction of fishing boats during the third 5-year economic development plan is as follows:

	1972	1973	1974	1975	1976	Total
No. of vessels	48	58	52	60	64	282
Gross tonnage	28,000	31,400	28,400	32,800	34,000	154,600

Improvement of Marketing System

To develop sales outlets abroad, it is necessary to secure refrigerated carriers and to reduce dependence on conventional sales systems. The first aim is to increase the marketing of fish by reducing losses through better processing and the proper storage of catches. The second is to develop an independent distribution system, which in the past has belonged to a foreign company.

The Government program for domestic construction of a fishing fleet can be related to the above aims. The Government is also surveying and analyzing current distribution systems and problems occurring in the marketing process.

Training of Fishery Technicians

As the number of vessels increases annually, it is necessary to train fishery experts and crews with a view to increasing efficiency in fishing and to prevent accidents during the fishery operations.

Cooperation with International Organizations

The basic Government policy is to promote, assist, and cooperate with the various programs over the entire field of fishery development and conservation of the ocean resources, so as to cope with the requirements of animal protein and general welfare of the peoples in the world. To carry out these tasks, Korea will cooperate in promoting the activities of international and regional organizations in the field of fisheries by collaborating in their various activities and research programs.

In regard to international research activities on the fishing ground, the Government established a 5-year survey program on deep-sea fishing grounds, as follows:

Year	Fishing method	Area
1972	Skipjack pole-line	Mid-western Pacific
	Trawling	South China Sea
1973	Skipjack pole-line	Mid-western Pacific
	Gillnetting	Indian Ocean
	Trawling	NW Atlantic
	Purse seining	Mid-eastern Atlantic
1974	Skipjack pole-line	Mid-western Pacific
	Tuna purse seining	Indian Ocean
	Shrimp trawling	SE Pacific
	Trawling, gillnetting	SW Atlantic or North Pacific
1975	Skipjack pole-line	South Pacific
	Trawling	South Atlantic
	Shrimp trawling	Indian Ocean
	Tuna purse seining	Indian Ocean
	Tuna longlining	Atlantic
1976	Skipjack pole-line	South Pacific
	Tuna purse seining	SW Atlantic
	Tuna longlining	Indian Ocean
	Shrimp trawling	Indian Ocean
	Trawling	SW Atlantic

Scientific Management of the World Stocks of Tunas, Billfishes, and Related Species[1]

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JOSEPH, J. 1973. Scientific management of the world stocks of tunas, billfishes, and related species. J. Fish. Res. Board Can. 30: 2471–2482.

This paper reviews past experience in tuna research and management, and proposes guidelines for the future. The resources discussed include three major groups: the six principal market species of tunas, which are heavily exploited; the billfishes, which are in most cases heavily exploited; and the secondary market species of smaller tuna and tuna-like fishes, which are generally underexploited. A brief review of their nomenclature, biology, and fisheries is given, followed by comments on the condition of the stocks. A discussion of institutional arrangements for the scientific study and management of tuna resources is presented, and such arrangements are examined in the light of problems which might be unique to tuna and tuna-like fishes. These special problems and ways in which they might be handled are considered.

L'auteur fait le point de l'expérience acquise dans les activités de recherche et d'aménagement relatives aux thons et propose des orientations pour l'avenir. Les ressources étudiées comprennent trois groupes principaux: les six grandes espèces commerciales de thons, qui sont fortement exploitées; les voiliers, qui sont fortement exploités dans la plupart des cas; et les espèces d'intérêt commercial secondaire, à savoir les petits thons et espèces voisines, généralement sous-exploités. La première partie du document traite brièvement de leur nomenclature, de leur biologie et de leur pêche; vient ensuite une étude sur la situation des stocks. Les arrangements institutionnels conclus en vue de l'étude scientifique et de l'aménagement des ressources en thons font l'objet d'un examen; ils sont analysés en fonction des problèmes que pourraient spécifiquement poser les thons et espèces voisines. Ces problèmes spéciaux et les solutions qui pourraient leur être apportées sont examinées.

El autor reseña cuanto se ha hecho en el campo de la investigación y regulación de las poblaciones de túnidos y propone directrices para el futuro. Los recursos examinados pueden dividirse en tres grupos importantes: las seis principales especies comerciales de atún, sometidas a una explotación intensa; los peces aguja, explotados también intensamente en la mayoría de los casos; y los pequeños túnidos y otros peces semejantes, secundarios desde el punto de vista comercial y subexplotados en general. En la primera parte del trabajo se estudia brevemente su nomenclatura, biología y pesquerías, completando esta información con observaciones sobre la situación de las poblaciones. Se examinan los acuerdos entre instituciones para estudiar científicamente y regular los recursos atuneros y, se analisan estos acuerdos a la luz de algunos problemas que tal vez sean exclusivos de los túnidos y peces análogos. En la última parte del trabajo se tratan estos problemas y las posibles formas de abordarlos.

THIS paper reviews past experience in tuna research and management, and proposes guidelines for the future. Resources discussed include three major groups: the six principal market species of tunas, which are heavily exploited; the billfishes, which are in most cases heavily exploited; and the secondary market species of smaller tunas and tuna-like fishes, which are generally underexploited.

The Animals and Their Exploitation

NOMENCLATURE AND BIOLOGY

The tuna and tuna-like fishes are grouped for economic reasons, because the majority of them are taken during the same fishing operations. In this paper three family groups will be discussed, the scombrids, xiphiids, and istiophorids. True tunas and tuna-like species, of which there are about 40, are usually classed in the Scombridae. Within this group are the six major tuna species (the principal market species) that comprise about 75% of world catches of tuna and tuna-like fishes. Also included with the scombrids are other species of tuna-like fishes. In an economic sense these are secondary market species, and their combined catch represents about 20% of the

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

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world catch of tuna and tuna-like fishes. The various species of billfishes, which include all members of the families Xiphiidae and Istiophoridae, are generally grouped as tuna-like from an economic point of view because the majority of them are taken by tuna fishing vessels while fishing for tuna, but in a biological sense they are not closely related to tunas. The billfishes account for about 5% of the world catch of tunas and tuna-like species. Table 1 lists species within taxonomic groups. The scombrids are divided into principal and secondary market groups. Somes species which are taken in limited amounts, such as *Thunnus atlanticus*, *T. tonggol*, *Allothunnus fallai*, and *Orcynopsis unicolor*, are not included. The mackerels *Scomber* and *Rastrelliger* are omitted.

Tunas and billfishes are highly specialized, fast-growing, very mobile organisms that spend their entire life on the high seas. They are generally encountered throughout all of the major temperate and tropical oceans of the world, primarily between 35°N and 30°S.

The six principal market species of tuna are classified, on the basis of geographical distribution, as either temperate or tropical, the latter including yellowfin, skipjack, and bigeye. Two of these, the yellowfin and bigeye, grow to large sizes (over 100 kg) and generally are short-lived, less than 5 years. Though skipjack are similar in many respects to the other two tropical species, individuals rarely attain a size greater than 15 kg.

The temperate species, albacore and bluefin, grow more slowly but live longer. There are often 5–15 age-groups in these fisheries at a time, whereas the fisheries for tropical tunas are supported by only 2–5 age-groups.

The secondary market species are both tropical and temperate, and like the major species have high metabolic rates and grow rapidly. Most do not attain large sizes, however, being generally less than 35 kg.

Most billfishes are found in tropical waters, but swordfish occur in highest concentrations in subtropical and temperate waters, and in many instances in commercial concentrations in waters of less than 15 C.

Most tuna and tuna-like species are highly mobile and in many instances undertake extensive migrations. In the Pacific Ocean the northern bluefin and albacore migrate between the nearshore waters off Mexico and the United States of America and those off the coast of Japan. In the Atlantic the bluefin travel between the Bay of Biscay and Mediterranean and the waters of the Gulf Stream off Canada and the United States of America. Albacore likely migrate as widely in the Atlantic as do bluefin. In the Pacific Ocean, skipjack undertake extensive migrations, travelling at least between the coastal waters of the eastern Pacific and the central Pacific. Yellowfin and bigeye tunas do not appear to be so highly migratory, apparently remaining within a couple of thousand kilometers of where they were born.

Southern bluefin tuna, found only in the southern hemisphere, migrate from spawning areas around the continent of Australia to the Atlantic, Pacific, and Indian oceans. Information on movements of the secondary market species is scanty, but these do not appear to be as migratory as do larger tunas. Billfishes, on the other hand, are quite migratory; some species of marlin and swordfish migrate several thousand kilometers.

METHODS OF HARVESTING AND FORMS OF UTILIZATION

Fisheries for tunas date back to prehistory. Harpoons, traps, and trolling gear are still used, but the major share of tuna today is captured by three more recent methods. The longline captures the largest share of tuna and tuna-like species. Three countries account for nearly all longline fishing, in order of importance, Japan, the

TABLE 1. Scientific, English, French, Japanese, and Spanish names of tunas and tuna-like species discussed in this report.

	English	French	Japanese	Spanish
Scombrids				
Principal Market Species				
Katsuwonus pelamis	skipjack	bonite à ventre rayé	katsuo	barrilete
Thunnus albacares	yellowfin tuna	albacore	kihada	atún aleta amarilla o rabil
Thunnus alalunga	albacore	germon	binnaga	albacora
Thunnus obesus	bigeye tuna	thon obèse	mebachi	atún ojo grande o patudo
Thunnus maccoyii	southern bluefin tuna	–	minamimaguro	atún del sur
Thunnus thynnus	northern bluefin tuna	thon rouge	kuromaguro	atún aleta azul
Secondary Market Species				
Sarda spp.	bonito	bonite à dos rayé	hagatsuo	bonito
Scomberomorus spp.	Spanish mackerel	thazard	sawara	sierra
Auxis spp.	frigate mackerel	auxide	sodagatsuo	melva
Euthynnus spp.	black skipjack	thonine	yaito	barrilete negro
Istiophorids				
Istiophorus platypterus	sailfish	voilier	bashokajiki	pez vela
Makaira spp. and *Tetrapturus* spp.	marlin	makaire	kajiki	pez aguja
Xiphiids				
Xiphias gladius	swordfish	espadon	mekajiki	pez espada

Republic of China, and the Republic of Korea. Next, in terms of landed weight of tuna, is use of live-bait to attract the schools of tuna. Third is the purse seine. This is vastly superior to other methods in terms of catch per unit of effort and is rapidly replacing bait fishing as the most important surface tuna fishing technique. Trolling with lures and with fishing traps, harpoons, and gillnets account for a large share of the catch of the secondary species, as well as a smaller share of the primary market species.

Tuna fisheries were not developed significantly until after the first world war and were not substantial until after the second world war. Fishermen of the United States of America fishing from Californian ports developed the live-bait tuna fishery in the eastern Pacific about 1915, and by 1945 they were fishing throughout the tropical waters as far south as Ecuador. During the same period the Japanese live-bait tuna fishery in the western Pacific expanded operations from near the Japanese mainland, eventually to include the entire Caroline Islands. Fishermen of France and Spain first began capturing tuna in the Bay of Biscay in significant quantities in the 1940s and shortly thereafter in waters off West Africa.

Minor fisheries for some billfish species have existed for a long time. Striped marlin and swordfish, particularly, have been harvested commercially in waters off California and Mexico since about 1915, and off Peru and Ecuador by subsistence fishermen long before that. In the Atlantic and Mediterranean, billfish have been captured for years in traps, but there were no substantial commercial fisheries until after 1950 when Japanese vessels began taking large quantities.

Tunas and billfishes are utilized in many forms. Of the scombrids, the majority are canned. The next most significant share is consumed in Japan as raw fish "sashimi," and in the third form as "katasuobushi," which is cured and dried. Of the billfishes, little is canned. Prior to 1960 most were eaten fresh but from 1960 to 1966 a large share of the catch was used in the manufacture of fish sausage and fish ham by Japan. Since 1966 the trend in Japan has been to consume the meat of billfish as sashimi; this can be attributed to the advancement in freezing techniques. This new market for billfishes has increased both the price and demand on a world scale.

DISTRIBUTION OF THE CATCH

Prior to the second world war the total production of the six principal market species of tuna never exceeded 300,000 metric tons/year. This began to increase rapidly after the war and by 1952 exceeded 450,000 metric tons. The catch then increased steadily until about 1961 when it levelled off at about 900,000 metric tons, and it fluctuated about that level until 1965. The catch increased slightly during 1965 and 1966 and by 1967 amounted to approximately 1,100,000 metric tons, and has remained at that level (Fig. 1).

On the basis of current available data I have attempted to improve the catch statistical data of the principal market species for 1971. A total catch of 1,212,500 metric tons is estimated, higher than the 1,071,000 metric tons in the preliminary FAO statistics (Table 2). These data are shown with similar information for secondary market species and the billfishes (Fig. 2).

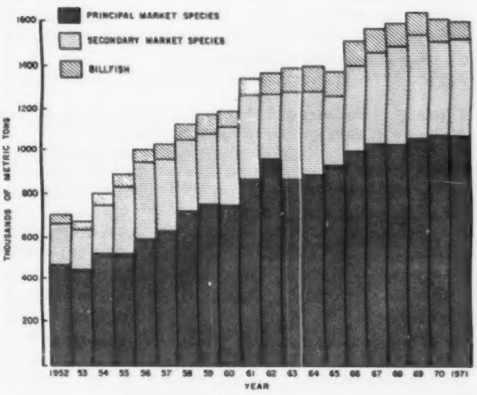
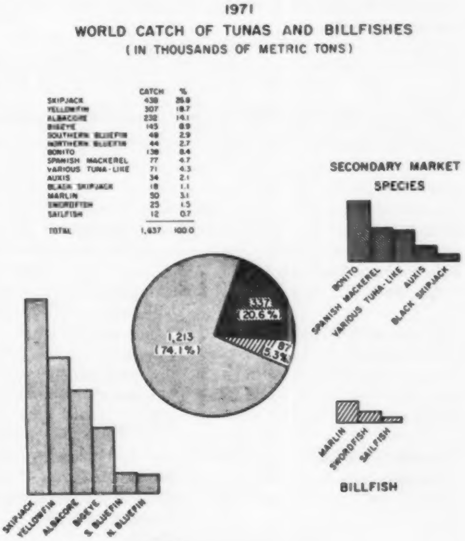


FIG. 1. Total catch of tunas and tuna-like species, as compiled by FAO, grouped within these categories of economic importance, for years 1952–71.



	CATCH	%
SKIPJACK	438	26.8
YELLOWFIN	307	18.7
ALBACORE	232	14.1
BIGEYE	145	8.9
SOUTHERN BLUEFIN	48	2.9
NORTHERN BLUEFIN	44	2.7
BONITO	138	8.4
SPANISH MACKEREL	77	4.7
VARIOUS TUNA-LIKE	71	4.3
AUXIS	34	2.1
BLACK SKIPJACK	18	1.1
MARLIN	50	3.1
SWORDFISH	25	1.5
SAILFISH	12	0.7
TOTAL	1,637	100.0

FIG. 2. The 1971 world catch of tunas and tuna-like species.

Of the principal market species, skipjack tuna represents 36.1% of the catch; yellowfin, 25.3%; albacore, 19.1%; bigeye, 12.0%; southern bluefin, 3.9%; and northern bluefin, 3.6%. These species represent 74.1% of the total catch of tunas and tuna-like fishes. The secondary species and billfishes represent 20.6% and 5.3%, respectively. Shares of the catch and species composition for each ocean are given (Fig. 3) for the principal species. Species composition for all species and all oceans combined is given in Table 3.

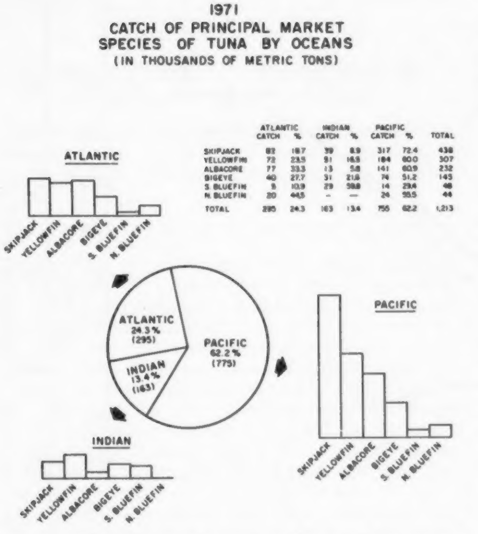
Because tuna and tuna-like fishes are so widespread, occurring off the coastlines of nearly all nations bordering tropical and temperate waters, the number of nations which engage in tuna fishing activities is large. During 1971 about 40 nations reported capturing tuna, but most

TABLE 2. Estimates of 1971 catches, in thousands of metric tons and in percentage (in parentheses) of the total catch, of the six market species of tunas, by oceans.

	Atlantic catch	Indian catch	Pacific catch	All oceans catch
		A. Author's estimates		
Skipjack	81.9(18.7)	38.9(8.9)	317.0(72.4)	437.8
Yellowfin	71.9(23.5)	50.7(16.5)	184.0(60.0)	306.6
Albacore	77.1(33.3)	13.4(5.8)	141.0(60.9)	231.5
Bigeye	39.5(27.2)	31.3(21.6)	74.3(51.2)	145.1
Northern bluefin	19.5(44.5)	0 (–)	24.3(55.5)	43.8
Southern bluefin	5.2(10.9)	28.5(59.8)	14.0(29.4)	47.7
Total	295.1(24.3)	162.8(13.4)	754.6(62.2)	1212.5
		B. From FAO preliminary statistics		
Skipjack	36.0(10.9)	0 (–)	294.0(89.1)	330.0
Yellowfin	78.0(26.3)	37.0(12.5)	181.0(61.1)	296.0
Albacore	77.0(35.0)	13.0(5.9)	131.0(59.5)	220.0
Bigeye	31.0(25.0)	29.0(23.4)	64.0(51.6)	124.0
Northern bluefin	33.0(57.9)	0 (–)	24.0(42.1)	57.0
Southern bluefin	4.0(9.1)	28.0(63.6)	12.0(27.3)	44.0
Total	259.0(24.0)	107.0(10.0)	706.0(66.0)	1071.0

TABLE 3. Estimated global catch of tunas and percentage of total catches for the year 1971, in thousands of metric tons.

			Percentage	
Group	Species	Catch	Of principal species	Of all species
Principal market species	Skipjack	437.8	36.1	26.8
	Yellowfin	306.6	25.3	18.7
	Albacore	231.5	19.1	14.1
	Bigeye	145.1	12.0	8.9
	Southern bluefin	47.7	3.9	2.9
	Northern bluefin	43.8	3.6	2.7
	Subtotal	1212.5		74.1
Secondary market species	Bonito	137.6		8.4
	Spanish mackerel	76.8		4.7
	Various tuna-like	70.5		4.3
	Auxis	34.2		2.1
	Black skipjack	18.3		1.1
	Subtotal	337.4		20.6
Billfish	Marlin	50.0		3.1
	Sailfish	12.0		0.7
	Swordfish	24.9		1.5
	Subtotal	86.9		5.3
Total		1636.8		



	ATLANTIC		INDIAN		PACIFIC		
	CATCH	%	CATCH	%	CATCH	%	TOTAL
SKIPJACK	82	18.7	39	8.9	317	72.4	438
YELLOWFIN	72	23.5	51	16.5	184	60.0	307
ALBACORE	77	33.3	13	5.8	141	60.9	232
BIGEYE	40	27.7	31	21.6	74	51.2	145
S. BLUEFIN	5	10.9	29	59.8	14	29.4	48
N. BLUEFIN	20	44.5	–	—	24	55.5	44
TOTAL	295	24.3	163	13.4	755	62.2	1,213

FIG. 3. The 1971 world catch of the principal market species of tuna by oceans.

of them catch small amounts (<1.0%). Six nations account for nearly 83% of the catch of principal market species, Japan and the United States of America accounting for nearly 60%; the other 34 nations catch the remainder.

Country	Principal market species Catch (thousands metric tons)	% of total
Japan	468.0	38.6
USA	238.6	19.7
Rep. of China	101.9	8.4
Rep. of Korea	73.8	6.1
France	71.6	5.9
Spain	49.8	4.1
Subtotal	1003.7	82.8
Others	208.8	17.2
Total	1212.5	100.0

MARKETING THE CATCHES

The two countries that catch the majority of the principal species of tuna consume the major share (Broadhead 1971). In 1969 Japan and the United States of America utilized about 75% of the world catch, or slightly more than their combined catch; Japan catches about 40% and uses 30%, while the United States catches about 20% and uses about 45%. During 1972, consumption of tuna by the United States will probably increase 20%. The nations of western Europe consume about 18% of the catch, the remaining 7% being distributed throughout the world.

Tuna has a world market, being consumed in most countries and shipped through most of the major ports of the world. It is priced roughly at the same level throughout the world. The total value of the 1971 catch of the principal market species in terms of equivalent United States dockside prices was more than $550 million (US).

TONNAGE CAPACITY OF THE INTERNATIONAL FLEET

To obtain some idea of the potential demand for raw tuna, and to evaluate whether such increased production is feasible, Joseph (1972b) examined recent trends in fleet size and growth. He reasoned that if fleet growth could be extrapolated it should be possible to predict production. Of course this reasoning would assume no biological constraint on production, and such an assumption is unrealistic. The discussion which follows is taken from the above paper.

Estimates of fleet size for the years 1958 through 1971 (Fig. 4) represent longliners, baitboats, purse seiners, trollers, and jigboats of approximately 20 nations, and together these account for more than 90% of the world catch of the principal market species of tunas. They should, therefore, provide an accurate index of trends in the fishery. During 1958 the international fleet had a total capacity of about 300,000 gross metric tons. An additional 100,000 tons were added in 1964 by Korea and China. Fleet capacity reached more than 700,000 tons by 1972.

In the early years, the annual catch of tuna (Fig. 4, from FAO statistics) increased more rapidly than fleet size, but in subsequent years decreased. The ratio of catch per gross metric ton declined 2.50 tons in 1958 to 1.48 tons in 1971. In terms of vessel production this catch per gross metric ton does not represent the entire catch. Many vessels fish other species in addition to tunas; in fact, billfishes are often the principal species sought by the longline fleet. The statistics of catch per gross metric ton should be indicative of trends, however, since the six species discussed in this report consistently comprise about 65% of the total catch of all tuna and tuna-like fish taken by the international fleet as reported by FAO.

Total fleet growth has been extrapolated (unconnected dots, Fig. 4). If catches of tuna remain as in 1970 and 1971, then with the projected fleet expansion the catch per gross metric ton should drop substantially (unconnected open circles). By 1974, assuming current catch levels, the catch per gross metric ton would dip to 1.30 tons, about half that prior to 1960. To maintain the 1970–71 level through 1974 the catch would have to increase about 20% (unconnected X's, Fig. 4), an additional 250,000 metric tons.

Status of the Stocks

Production of tuna from the world's oceans has increased substantially during the past 25 years. From 1950 to 1961 it nearly doubled, and from 1961 to 1967 it increased by about 15%. Consumption in the United States of America alone has nearly doubled every decade since 1920 (Chapman 1967). The demand is expected to continue to increase not only there but throughout the world. The important question is whether the resources of tuna are capable of filling this demand.

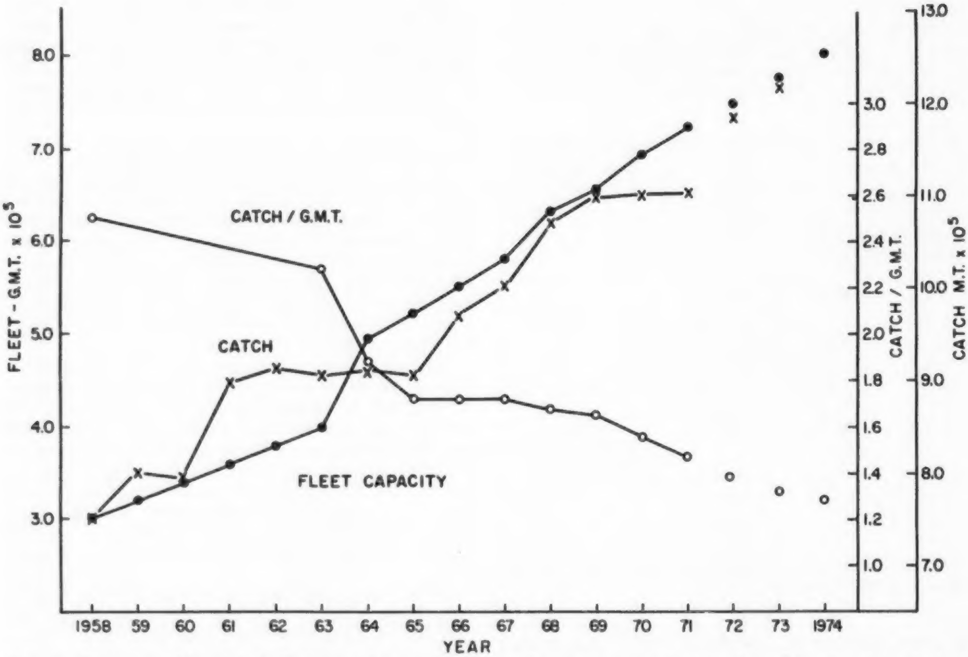


FIG. 4. Recent world trends in fleet capacity, catch, and catch per gross metric ton of capacity, for the principal market species of tuna, 1958–71, with extrapolations through 1974.

It does not appear that production can be increased at the rate of the great expansion of the 1950s as the catch has remained rather constant since 1967 in the face of increased fleet growth. Of great importance is whether we can expect any growth, or whether production of the principal species may be reduced due to overexploitation.

The most complete discussion of this question is that presented by experts convened by FAO in 1968 (FAO 1968), and a subsequent group convened in 1969 (FAO 1969), and reviewed by Joseph (1972a, b). In summary, the information suggests that most of the principal market species of tuna are nearly or fully exploited. Yellowfin, albacore, and bigeye tuna appear to be nearly fully exploited, and increased effort on these species will result in at best small increased catches and even in decreased catches. Northern bluefin tuna in the Pacific Ocean are probably fully exploited, and in the Atlantic Ocean are possibly overexploited. Albacore tuna appear to be fully exploited in all three oceans and increased production is not likely. Southern bluefin tuna has been heavily exploited recently and catches have declined by about 30% .The Japanese, who catch the major share of this species, have initiated self-imposed regulations in this fishery. Skipjack tuna, the largest component (36.1%), is taken in large quantities in the three oceans. Judging from biological data, this species appears to be underexploited throughout most of its range; thus present production might be substantially increased. A possible exception to this is in the western Pacific, where Japanese studies have suggested the catch may be approaching its upper sustainable limit.

For the secondary market species few assessments of the stocks have been made. Gulland (1972) has commented briefly on some, concluding that for bonito (40% of the catch), catches are probably nearing the upper sustainable limit, although limited expansion of effort is possible. For the other species effort can probably be increased substantially, and catches should increase. Gulland estimates that in the eastern Pacific alone the catches of frigate mackerel may be increased to 200,000 tons. Judging from the widespread distribution of this species, the world potential must be considerably higher. Another important secondary species which can probably be increased substantially is black skipjack. Research is urgently needed on these species to evaluate their potential. However, it should be emphasized that the demands for tuna stated by Chapman refer to the six principal market species and not the secondary species. In most countries the latter cannot be labelled tuna.

Little research has been done on the dynamics of billfish stocks. Fishing effort by longline gear, the main method, has been increasing during the last few years, but catches have remained rather steady. Gulland (1972) has suggested that they are probably fully exploited and increased production is not likely. For some species in certain areas overexploitation has apparently occurred (Tibbo and Sreedharan 1972).

Present International Arrangements for the Scientific Management of Tuna

Several international organizations are concerned with management and there are two whose sole function is to provide guidance for establishment of controls on exploitation.

INTER-AMERICAN TROPICAL TUNA COMMISSION (IATTC)

The IATTC was established by convention between Costa Rica and the United States of America in 1949. It is an open-ended convention in which any state may join whose nationals participate in the fisheries covered by the convention, providing acceptance is given by all members. Five countries, Panama, Ecuador, Mexico, Canada, and Japan joined subsequently. Ecuador withdrew in August 1968. The convention waters are referred to as the eastern Pacific Ocean but are undefined in terms of longitude and latitude. The species of fish covered by the convention are yellowfin tuna, skipjack tuna, baitfishes used to capture tuna, and other tuna and tuna-like fishes captured by tuna vessels in the eastern Pacific Ocean.

The IATTC consists of national sections, each comprising one to four commissioners appointed by the member governments. All decisions, resolutions, recommendations, and other official actions of the Commission must be by unanimous vote of all High Contracting Parties. A Chairman and Secretary are elected at annual meetings, which are held at least once each year. A Director of Investigations is responsible for appointment and direction of scientific and technical staff. Of paramount importance among duties of the IATTC is responsibility to make recommendations, on the basis of scientific investigations, for action by the High Contracting Parties to keep the stocks of fishes at levels of abundance permitting the maximum catch on a sustained basis.

The Commission initiated its research program in 1950. The staff set about collecting historical records of catch and nominal fishing effort for the fishery, and established a system of logbook information with which catches and nominal effort could be monitored on a semi-current basis. Such data formed the basis of studies on the dynamics of the fishery; they were supplemented by the staff's intensive studies on the biology and ecology of the major tuna species of the eastern Pacific Ocean.

On the basis of these studies, estimates were made of the sustainable yield of yellowfin prior to overexploitation. (For skipjack tuna, the other species which was studied extensively, analysis indicated that it was not fully exploited.) As fishing effort increased in the eastern Pacific Ocean, overfishing of yellowfin occurred in the early 1960s. Catch quotas were recommended but these were not implemented until 1966. The fishery for yellowfin tuna has been under management since that time. The management program of the IATTC has been reviewed in detail by Joseph (1970, 1973). In summary, the program is based on a general catch quota, to be taken on a first-come-first-served basis. The quota is established each year, and applies only to the Yellowfin Regulatory Area (CYRA), established on the basis of information concerning stock structure available in 1961.

Since 1966 the fishery in the eastern Pacific has changed remarkably and the management program has also changed in an attempt to be responsive. The fleet has increased nearly three times since 1966. Competition has increased sharply and the open season for yellowfin fishing has decreased from about 10 months to less than 3. As competition increased, a portion of the overall quota has been allocated to meet the needs of countries with fleets having special economic problems. Catch quotas in the CYRA have been increased experimentally, since the fishery is expanding geographically and is fishing on a larger portion of the population than it had previously. A major problem of the Commission is related to distribution of the catch. All fleets are growing rapidly, but the fleet of one nation (the United States of America) comprises about 75% of available capacity and captures nearly 85% of the catch from the CYRA. Developing nations maintain that under the present management system their tuna fisheries cannot develop, and there are strong pressures for increased special allocations. As these allocations are established there is beginning to be a shift of flag vessels from the nations with large fleets to the nations with small fleets. Each nation with vessels fishing in the CYRA is responsible for establishing and enforcing its own tuna regulations based on the recommendations of the IATTC. As vessels relocate in other countries the number of nations involved increases, along with problems of implementation and enforcement.

INTERNATIONAL COMMISSION FOR THE CONSERVATION OF ATLANTIC TUNAS (ICCAT)

A convention for the establishment of the International Commission for the Conservation of Atlantic Tunas (ICCAT) was signed in Rio de Janeiro in 1966. Seven ratifications were necessary to bring the convention into force, and these were obtained in 1969. The convention waters comprise all waters of the Atlantic Ocean, including the adjacent seas. The Commission is responsible for the study of populations of tuna and tuna-like fishes (the Scombriformes with the exception of the families Trichiuridae and Gempylidae and the genus *Scomber*) and such other species of fishes exploited in tuna fishing in the convention area as are not under investigation by another international organization.

The convention is open for signature by any member of the United Nations or any of its Specialized Agencies. At present there are 13 members; Spain, France, Brazil, Canada, USA, Japan, Morocco, Portugal, Republic of South Africa, Ghana, Republic of Korea, Senegal, and the Ivory Coast.

Each of the contracting parties is represented in the Commission by not more than three delegates, who may be assisted by experts and advisers. Decisions of the Commission are made by a majority of the contracting parties, and two-thirds of the contracting parties constitute a quorum. Regular meetings are provided for once every 2 years.

The convention of ICCAT provides for research to be accomplished through: (1) technical and scientific services of official agencies of the contracting parties and their subdivisions, (2) available services and information of any public or private institution, organization, or individual, (3) independent research (within limits of its budget) not accomplished under (1) and (2). ICCAT may establish panels on the basis of species, groups of species, or geographical areas. The Commission has established four panels: (1) tropical tunas, yellowfin and skipjack; (2) temperate tunas (north), bluefin and albacore in the northern hemisphere; (3) temperate tunas (south), bluefin and albacore in the southern hemisphere; (4) other species, bigeye, bonito, billfish, and others. Such panels are responsible for monitoring populations of fish under its purview and collection of information to do so, and for proposing to the Commission, on the basis of scientific evidence, recommendations for joint action by the contracting parties. On the basis of scientific evidence the Commission may make recommendations to the contracting parties, designed to maintain populations at levels which will permit the maximum sustainable catch.

The ICCAT has chosen not to exercise its option to conduct independent scientific research. It has only a minimal staff, which includes an Executive Secretary, an Assistant Executive Secretary, and a small number of supporting administrative and clerical assistants. A Standing Committee on Research and Statistics (SCRS) has been established to recommend and guide research to be conducted by scientific organizations of its member governments. The SCRS has a number of subcommittees and working groups, comprised of scientists of its members and outside experts, to examine special scientific problems. To date the SCRS has been concerned primarily with mechanisms for the collection of catch and effort statistics for the major tuna fisheries of the Atlantic, and with assessment of stocks of yellowfin and bluefin tuna in that ocean. A major constraint on assessment of the stocks has been lack of data on catch and fishing effort.

During the 1972 Meeting a minimum size limit of 3.2 Kg was recommended for yellowfin tuna, but decisions on the need for minimum size limits on bluefin and catch quotas on yellowfin were not made.

Indian Ocean Fishery Commission (IOFC)

Two additional international organizations concerned with research, development, and management of all species of fish within their geographical area of competence include tunas in their considerations. The structure of these organizations is different from the two tuna commissions in that they are established within the framework of the FAO.

The Indian Ocean Fishery Commission (IOFC) was established by the Council of FAO under Article VI-1 of the FAO Constitution on the recommendation of FAO's Committee on Fisheries (COFI). Membership is open to all Member Nations and associate members of the FAO. There are now 28 members. The IOFC's geographical area of responsibility is the Indian Ocean and adjacent seas, excluding the antarctic area. The species of living marine resources with which it is concerned are not limited.

The objectives of IOFC are: 1) to promote, assist, and coordinate national programs over the entire field of fishery development and conservation; 2) to promote research and development activities in the area through international sources, and in particular international aid programs; 3) to examine management problems, with particular reference (because of the need to take urgent action) to those relating to the management of offshore resources.

The Commission elects a Chairman and up to six Vice-Chairmen at the end of each biennial session, but is not structured to support a research staff of its own. To accomplish its tasks it may establish subsidiary bodies as well as call upon outside expertise. With reference to problems of conservation in the Indian Ocean the IOFC has established a Committee on Management charged with recommending, on the basis of scientific evidence, measures to prevent overfishing. This Committee has a working party on stock assessment, in relation to immediate problems of management in the Indian Ocean, which has confined its activities to tuna. On two occasions it has examined data in order to assess the impact of fishing on the stocks of Indian Ocean tuna. Though they were able to make preliminary assessments, meaningful analysis was impossible without much improved statistical data. The major recommendations of this group have been for the collection of catch statistical information.

Indo-Pacific Fisheries Council (IPFC)

The Indo-Pacific Fisheries Council (IPFC) was formed in 1948 within the framework of the FAO under the provision of Article XIV of the FAO Constitution. Its membership is open to all members and associate members of FAO, and such nonmembers as are members of the United Nations. Its area of concern includes the marine and fresh waters of the Indo-Pacific region; the species with which it is concerned are undefined.

The terms of reference of the IPFC are broad and include: (1) to formulate technical aspects of problems of development and encourage proper utilization of living aquatic resources; (2) to coordinate and encourage research and dissemination of results therefrom; (3) to recommend and undertake development projects within its member nations; (4) to propose and adopt measures to bring about standardization of scientific equipment, techniques, and nomenclature.

A Chairman and Vice-Chairman are elected at each regular session of the IPFC but no provision is made for a research or technical staff. The IPFC has established a committee on tuna management in the Indo-Pacific region, but at present it is concerned with the western Pacific. Little has been accomplished by IPFC with regard to the assessment of tuna within its region.

Other Arrangements

Species of highly migratory animals which spend only a portion of their life within the territorial waters of a coastal state cannot be managed by the coastal state alone because controls applied to such resources when in territorial waters do not apply when the fish are on the high seas. The most effective means for managing resources which range over vast ocean areas has been through international conventions. Though many of these have been ineffectual, they provide the only examples of moderately successful high seas management programs in existence (Chapman 1970; Lagarde 1972). During the last two decades a large number of fisheries commissions and international organizations have been established, suggesting that such bodies offer one of the best means for dealing with international fisheries problems.

Comparison of Present Commissions

All four tuna bodies (IATTC, ICCAT, IOFC, and IPFC) are concerned with conservation of tuna and tuna-like species within their areas of geographical responsibility. The IATTC and ICCAT are independent commissions established by international treaties and are therefore responsible to the contracting parties. The IPFC and IOFC are established within the FAO and are regional bodies subject to control of the FAO Conference and Council; their activities are carried out through their parent body (Carroz and Roche 1967). The ICCAT has an agreement which provides for appointment of an FAO representative who participates, without the right to vote, in meetings of the Commission and its subsidiary bodies.

All four bodies are similar in that their treaties and agreements contain no provision on their legal status, nor do they specify their capacity under international law or national legal systems to perform their duties. This is common to all intergovernmental fisheries bodies except one, the International Council for the Exploration of the Sea, which provides for such legal status and capacity in its convention. Though international fisheries bodies have not been granted legal status they have nevertheless been able to perform legal acts necessary to their objectives on an ad hoc basis, including contracts and transactions relating to the purchase of equipment, hiring of staff, chartering of vessels, and leasing of premises. However, there is no basis for these organizations to enforce their rights, and in certain instances the lack of legal status has obstructed the timely performance of their duties. Even though these ad hoc arrangements have generally sufficed to permit operation of the international bodies in the past, it would appear desirable that conventions creating such bodies include a provision establishing their legal capacity to perform acts necessary to accomplish these duties.

Methods for funding the four bodies differ markedly. IATTC and ICCAT funds are contributed by the member governments in a prescribed manner. Members of IATTC pay in proportion to the amount of fish originating from within the convention waters utilized by each member, regardless of who captured it. Contributions by member states of the ICCAT are determined on the basis of catch and utilization, and by membership on panels. The conventions of IOFC and IPFC do not provide for an operating budget; these commissions rely on the FAO for support.

With regard to commission staff, two kinds of arrangements have been made: IATTC has a full scientific research staff, under the supervision of a Director of Investigations; IPFC has no staff except an elected Chairman and Vice-Chairman, and relies on committees composed of member countries to do technical work. Between these extremes is ICCAT which has a permanent secretariat to attend to administrative matters but relies on panels and committees composed of scientists from national sections for research.

There are pros and cons concerning scientific staff within international fisheries commissions. Most of these revolve about the acquisition of basic data, primarily catch statistics, and the conduct of independent research, free of national policies. A discussion has been presented in Joseph (1972a), who concluded that because of the technological and economic development of the major share of the tuna-fishing nations, the widespread distribution of the resources, fleets and markets, the high-seas nature of the tuna themselves, and the success of fisheries commissions with research staffs, commissions could attain their objectives more efficiently if they maintained independent research staff.

The four bodies differ regarding the geographic areas and species of fish for which they are responsible, as described in detail in foregoing sections. Thus the world oceans have been partitioned into regional areas for the purposes of tuna management. The question is whether this is the best way to approach the problem.

Consider the distribution of the animals which are the objects of management. Research has shown that tunas are in general highly migratory. Albacore and northern bluefin tuna make transoceanic migrations; in 1 year albacore off the east coast of Japan migrate to the west coast of North America. Northern bluefin tagged off the eastern United States of America have been recovered in northern European waters, in the Bay of Biscay, and off Brazil. Catch information suggests that albacore and yellowfin found in the southeast Atlantic Ocean may occur later in the southwest Indian Ocean. Skipjack tuna migrate from the eastern Pacific, where they are only seasonal visitors to the central Pacific Ocean. Recent studies based on genetics of protein systems suggest that a single skipjack subpopulation occurs from the mainland of the Americas to about 150°E, and a second subpopulation from there to mainland China. Southern bluefin tuna are a single, intermingling population distributed circumpolarly throughout the Atlantic, Indian and Pacific Oceans. Yellowfin tuna are more migratory than originally thought. Thus tunas do not recognize imaginary boundaries, and those created by the four commissions are not realistic for management.

Problems of imaginary boundaries can include those introduced by jurisdictional claims of the coastal states, regardless of the breadth of such zones. The animals themselves do not recognize these boundaries and tuna conservation programs based on them will not work. No unilateral or multilateral action taken within territorial seas, whatever the breadth, will lead to proper management. Therefore, in formulating fisheries conventions, the convention area with respect to scientific research and management should include all areas within the range of the fish under study including, if appropriate, the territorial waters of the coastal states. An example is the IATTC, whose convention waters are the eastern Pacific. It has already been demonstrated that for skipjack tuna certainly, and for yellowfin tuna possibly, the westward extent of the convention waters does not include the entire range or population of animals. The southern bluefin tuna will present even greater problems if it becomes necessary to manage this species, because they comprise a single subpopulation and occur within the convention waters of all four bodies. The geographic areas of responsibility need to be based more on biological parameters and less on political ones.

Not only are the fish themselves highly migratory but the fleets that capture them operate over vast areas. In a single year one vessel may fish in the Atlantic, Pacific, and Indian oceans. When management decisions are made, this great fleet mobility must be taken into account.

With regard to management, only the IATTC has implemented a regulatory program. (The ICCAT has recommended a minimum size limit for yellowfin tuna but this will not become effective until 1973.) The first step in implementing regulations is a recommendation for management based on scientific evidence from the Commission's staff. The Commission recommends action to the Contracting Parties. The Commission also actively seeks cooperation in the conservation program of nonmember governments who fish for tuna in the eastern Pacific. Each participating nation implements the regulations which apply to their vessels. Responsibility for enforcing these regulations lies within each country. Tuna fleets are developing in many nations who had none or small ones at most. As these fleets grow it becomes of tremendous importance that legislation and mechanisms for enforcement be established by the countries. This is even more significant if we note that the Tuna Conventions Act of the United States of America states that regulations for the control of tuna fishing in the convention waters shall not be promulgated ". . . prior to an agreed date for the application by all countries whose vessels engage in fishing for species covered by the conventions in the regulatory area on a meaningful scale, in terms of effect upon the success of the conservation programme, of effective measures for the implementation of the Commission's recommendations applicable to all vessels and persons subject to their respective jurisdiction. The Secretary of the Interior shall suspend at any time the application of any such regulation when . . . he determines that foreign fishing operations in the regulatory area are such as to constitute a serious threat to the achievements of the objectives of the Commission's recommendations."

The United States is the major producer of tuna in the Convention area, and without the participation of the United States there could be no effective program.

The establishment of national agencies to enforce laws on a high-seas fishery such as tuna is complex and expensive — so much so as to impede the entrance of some developing nations into the tuna fisheries. Serious consideration should therefore be given to international enforcement or inspection systems for tuna fisheries. However, it is most important when considering establishment of such systems that they be kept separate from the scientific arms of commissions, for when scientific and enforcement functions are combined, both suffer.

Future Arrangements

In the earlier sections of this paper it was shown that the combined catches of the principal market species of tuna have remained relatively constant recently though fishing effort has increased substantially. For some of these species catches have declined sharply over earlier levels. Similarly, combined catches of billfishes have not increased in recent years though fishing effort for them has increased, and for some billfish species catches have declined. With four research and management bodies for tuna in existence, why is total catch stabilized and the catch for some species declining? Something in the present institutional arrangements is inadequate. The most obvious shortcoming is a lack of adequate data on catch and fishing effort.

Statistics of total catch by species, and estimates of the amount of fishing effort, in terms of days fishing, days absence, tons of capacity at sea per month, etc., from a significant sample of the fleet are fundamental to the study of fishery dynamics. Of nearly equal importance are samples of length measurements, which represent the size distribution of the exploited population. The IATTC handled this problem with its own scientific staff, whose first task was collection of these data. The other three bodies were not provided with research staffs. ICCAT has a permanent secretariat which has made a heroic effort to compile statistics, but a lack of funds makes the task nearly impossible. The IOFC and IPFC have no staff for collection and compilation of such data, and assessment of their tuna stocks has been impeded.

On numerous occasions scientists have stressed the need for adequate statistics for the tuna fisheries, and have predicted the difficulties that would be faced without them. At the FAO-sponsored World Scientific Meeting on the Biology of Tunas and Related Species, held in La Jolla, California, in 1962, a special working group was established to consider the problem of catch and effort statistics. The group pointed to the shortcomings of the then current collections and suggested mechanisms for improvement (FAO 1963). The Expert Panel for the Facilitation of Tuna Research, established by FAO, has similarly on numerous occasions pointed to the strong need for better statistical data (FAO 1964, 1966). Likewise, a group of experts discussing the dynamics of world tuna stocks pointed to the urgent need for much improved statistics of catch and effort (FAO 1968). All of these recommendations were made a number of years before the tremendous expansion of the world tuna fleet took place, but little was done. Only now are political sectors recognizing the urgent need for statistical data. A recent joint meeting of a Special Committee on Management of Indi-Pacific Tuna recommended that a staff of several professionals, plus supporting staff, be established to obtain the necessary statistical information for adequate scientific assessment of tuna stocks in the Indo-Pacific region. At the Second Regular Meeting of the Council of ICCAT, a resolution was adopted which pointed to the deficiencies in Atlantic tuna catch-effort statistics and the need for adequate funding of the Secretariat to collect better data. The resolution recommended as an interim measure that member governments assist in the data collection by offering to provide technical experts to the ICCAT Secretariat.

The awareness that catch statistical data are essential to the study of tunas is gratifying to scientists, but this is only part of the problem. Of equal importance is analysis, because it provides the assessments of stocks necessary to recommend management measures.

How can present arrangements be modified to obtain the objectives of rational harvest? One way might be to provide ICCAT, IOFC, and IPFC with their own staffs, with sufficient funds and personnel to collect and analyze statistical data on their fisheries. Before discussing this let us examine several points emphasized earlier.

The total catch of tuna is taken by approximately 40 countries. Of these, two countries, Japan and the United States of America, take about 60% and utilize about 75%; six take nearly 85% and 36 countries catch the remaining 15%. Tuna are wide-ranging, highly migratory fish. They make transoceanic migrations and do not recognize boundaries. Fleets that capture tuna are highly mobile; individual vessels can and do fish tuna in all oceans during a single year.

Considering these factors, it would be redundant and economically inefficient for four bodies to work on nearly identical problems in isolation. At a minimum these should be a single entity responsible for collection of statistical information. This could be accomplished by the creation of a new body or by expansion of responsibility in an existing one. Likewise, because the collection of data and its subsequent analysis are so closely interwoven, it would appear most practical that the same body do both. This was pointed out by the FAO group of stock assessment experts cited above:

"There is an urgent need for an improvement in the statistics of total landings, species composition, and fishing effort. Because of the nature of the fisheries, long-range vessels and vessels landing in foreign countries, the collection, tabulation and publication of detailed statistics might be better done for the world as a whole, rather than for each ocean separately."

They go on to state:

"The Pacific tuna fishery is based on the same species, is largely carried out by the same countries (and indeed, often the same vessels), and supplies the same market as the Atlantic and Indian Ocean Fisheries. It is therefore unrealistic to consider any one of these oceans in isolation as regards statistics, scientific research or management."

Others have pointed to the need for a more integrated approach to the problem of research and statistics. Rothschild (1970, 1973) has extended the need for such an integrated approach to all aspects of fisheries research and management, including sociopolitical and economic ones. He has suggested that we have not adequately recognized the need to develop techniques to handle these complex problems of fisheries management. He has discussed systematic techniques for studying such problems on a broad and comprehensive basis. Such an approach appears necessary to develop research and management programs for tuna that recognize the complexity of the fishery.

All these facts suggest the need for a single body with responsibility for collection of statistical data on tuna fisheries of the world, assessment of the condition of the stocks supporting these fisheries, and subsequent recommendations for management.

This concept is by no means new and has been discussed in detail by, among others, Kask (1969), Joseph (1972a), and Gulland (1972), and it formed one of the major agenda items at the recent meeting of the FAO's Committee on Fisheries.

Such an arrangement could be structured in a number of ways, but one which appears practical is to establish a scientific group whose responsibilities would apply to the tuna fisheries of the world, and would include inter alia: 1) collection and compilation of basic catch-statistical data, size-composition data and other biological information; 2) scientific analysis of such data to assess the effect of man's activities on the abundance of the stocks of tuna under study; 3) timely advice to the High Contracting Parties on the condition of the stocks of tuna; 4) if and when management programs are implemented, the current (on a nearly daily basis) collection and estimation of total catch by gear, area, and flag, to establish closure dates, areas, and other forms of regulations.

Such a scientific group would have to be funded and administered by some political entity. The scientific arm of the body would need to be endowed with its own research staff and a sufficient budget to carry out its duties. Its responsibilities should include all species of tuna and tuna-like fishes listed in the FAO Yearbook of Fishery Statistics which spend all or part of their life on the high seas. Its geographic area of responsibility should be worldwide. Its primary concern should be with the principal market species and billfishes; however, it could provide excellent background data and guidelines for development of fisheries on the secondary species.

The political body could be structured in a number of ways. It could be a number of regional groups, or a single body. The latter would appear to be most efficient but may be more difficult to establish and administer. Its responsibilities would be to make recommendations for management to the High Contracting Parties on the basis of advice from the scientific arm. Its responsibility could include all the tuna and tuna-like species wherever they occurred. Its membership would be open to all nations who are engaged in tuna fisheries, and not restricted to the United Nations or FAO family of nations. The major tuna-fishing nations, those capturing and utilizing in excess of, say, 75% of the total catch of tunas, would need to be members. The objectives of the political body should not be too restrictive with respect to conservation. For example, it should not be limited to the attainment of maximum physical yield, but should be free to examine alternate forms of management which might be optimized through consideration of economic, social, and other factors. This could include an arm composed of economists and political scientists to advise the political body on such matters. The political body should also be authorized to recommend an international inspection system or enforcement arm to facilitate implementation of its recommendations for conservation.

Whether a format for future study and conservation of tuna such as the one outlined above or some other arrangement is instituted, it is clear that some alteration of existing arrangements is required. It must be responsive to the dynamic nature of the fish themselves and of their fisheries; it must be responsive to the needs of the developing tuna fishing nations and of those already highly developed, and it must consider problems of tuna research and management over a broad time horizon.

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Report on Technical Session IV — Section 6

General

1. Although distant-water fishing in the North Atlantic has been carried on for centuries, for the most part it is a development of the last 20 years. The major fleets belong to a few large technically advanced countries, but several less developed countries have now acquired substantial capacity.

2. Vessels fishing within 1000 miles of their bases usually return home with their catches. For greater distances the catch is usually loaded onto transport vessels, and the fishing craft are serviced from supply ships. Large tuna seiners and longliners can operate at great distances and bring the catch home frozen, or trans-ship it at intervals.

3. For countries with large populations, distant fishing is a means of meeting general protein requirements or a demand for favored species. For developing countries such a fleet may be important either directly for food or as a means of earning foreign exchange.

4. The opinion was expressed that distant fishing (except for stocks found only on the high seas) would gradually decline for economic reasons, being more expensive than shore-based operations. An intermediate stage in this process could be joint ventures with coastal states.

5. Some of the less developed countries would like to start distant fishing on at least a modest scale, following the example of Cuba, Ghana, and Korea. This requires both determination and a certain amount of assistance. There is need for infrastructure, vessels, training programs, and a willingness of local people to spend long periods at sea.

Effects on Stocks Fished and on Shore-Based Fisheries

6. One effect of the expansion of distant-water fishing has been to harvest many stocks that previously were fished only lightly or not at all. Thus the world take of protein has been substantially increased.

7. Some distant-water fleets have attacked stocks which adjacent countries regarded as already fully utilized or nearly so, thus substantially reducing the take by coastal fishermen. Examples are the Georges Bank haddock, the Argentinian castaneta, the salmon of the North Pacific, and certain whale stocks off South America. Particular concern was expressed of the effect on local artisanal fisheries, for example in northeastern South America.

8. In some places distant-water fleets operate primarily on stocks that are not of local interest. This can have a variety of effects. They may take a valuable species incidentally, in quantities that are fairly large in relation to its stock, even if these quantities are small in relation to the total production of the distant fleets. Alternatively, they may increase the production of a locally valuable competitor or prey species. Only careful research can reveal the true situation.

9. Because of the magnitude and mobility of long-range fleets, their operations raise special problems in relation to the management of the resource. Few large fish stocks capable of supporting the operation of distant-water fleets now remain less than fully exploited. The continuing increase in the size and capacity of distant-water fleets, especially from highly developed countries, is therefore a matter of serious concern. It is essential that the activities of these fleets should be properly controlled in accordance with the knowledge of the resource, to ensure the proper conservation and management of the resource.

10. It was stressed that countries adjacent to a fish resource have the right and responsibility to participate in the study and management of a resource, whether or not they are currently engaged in its exploitation.

11. Except in some special cases, such as the harvesting of Antarctic krill, which would always be carried out by long-range fleets, locally based fisheries should be developed to harvest resources. To some extent economic factors, such as reduced traveling time, favor this development, but developing countries need technical and economic assistance from the developed countries.

12. Exploitation by distant fleets will reduce the abundance of local stocks and may make it more difficult for a shore-based operation to begin, particularly in less developed countries. On the other hand it has sometimes happened that coastal operators were first stimulated to activity by the sight of successful long-distance fishing off their shores.

13. The larger species of tunas and billfishes are already exploited to their limit through most of the world. The most recent doubling of fishing capacity yielded little increase in catch, yet many additional vessels are being built. Thus a serious economic problem looms, one which will make management increasingly difficult.

Research and Management

14. Many, possibly most, long-distance fisheries today operate within the constraints of commissions or agreements of various sorts. Also, the nations involved are among the major contributors of research data to such organizations. In any event *all* nations that participate in an international fishery have an obligation to contribute data relative to its management.

15. Because of the long range of modern tuna vessels they can be deployed in any ocean at different times of year. Thus the only effective management device may be a single worldwide agreement. Otherwise, any reduction in fishing in a given place will increase the intensity elsewhere.

Western South Atlantic

16. Concern was expressed that the Conference had not dealt specifically with the Western South Atlantic. The countries in the area would like to avoid the problems which have arisen in other regions, and to take advantage of worldwide experience. It was suggested that there should be a multilateral agreement to encourage the study of the resources of the region in order to achieve their most effective use.

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FAO Technical Conference on Fishery Management and Development

CLOSING SESSION

The Challenge of the Future

CHAIRMAN: A. W. H. NEEDLER, CANADA

Problems Confronting Fishing Industries Relative to Management Policies Adopted by Governments[1]

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ELLIOT, G. H. 1973. Problems confronting fishing industries relative to management policies adopted by governments. J. Fish. Res. Board Can. 30: 2486–2489.

With increase in numbers, size, and effectiveness, fishing fleets have depleted important stocks of fish, and strong international action by governments is imperative for the future viability of fishery resources. The author favors a system of an overall quota of fish, with individual quotas for boats and plants, and predicts that this will become "the accepted method of running fisheries" in 20 years. He discusses how best to organize such a system, with full consultation between governments and their national fishing industries as well as at the international level. For efficient handling of the complex issues involved and a full understanding of them, he suggests that governments should appoint to their fisheries ministries officers who have specialized in fisheries management and are able to analyze the situation in depth and advise the administrators on the implications of alternative management policies. The controls over fishing that he advocates are essential because "free fish means eventually no fish."

Ayant augmenté leurs effectifs, leur dimension et leur efficacité, les flottilles de pêche ont épuisé d'importants stocks de poissons et il est impératif que les gouvernements prennent des mesures rigoureuses à l'échelon international pour assurer la viabilité future des ressources halieutiques. L'auteur prône un système de contingentement global, avec fixation de contingents individuels par bateau et usine, système qui, à son avis, sera d'ici une vingtaine d'années "la méthode acceptée d'exploitation des pêcheries." Il examine les meilleurs moyens d'organiser un tel système en consultation étroite entre les gouvernements et leurs industries halieutiques nationales, ainsi qu'au niveau international. Pour bien comprendre et résoudre avec efficacité les problèmes complexes en jeu, l'auteur suggère que les gouvernements affectent à leurs ministères des pêches, des fonctionnaires spécialisés dans l'aménagement des pêches et capables d'analyser la situation de manière approfondie et de conseiller les administrateurs quant aux incidences des diverses formules d'aménagement. L'auteur déclare que le contrôle de la pêche qu'il préconise est indispensable car "la liberté de la pêche aboutira en fin de compte au dépeuplement des mers."

Con el aumento del número, dimensiones y rendimiento, las flotas pesqueras han agotado poblaciones importantes de peces y los gobiernos tienen que tomar medidas internacionales enérgicas para proteger los recursos pesqueros. El autor está a favor de un sistema de cupos totales de pesca con otros individuales para las embarcaciones y fábricas, prediciendo que éste será "el método aceptado de explotar la pesca" de aquí a 20 años. Examina la mejor forma de organizar dicho sistema, celebrando consultas entre los estados y sus industrias de pesca, e internacionalmente. Para comprender y solucionar las cuestiones complejas que trata, el autor sugiere que los estados nombren en sus ministerios de pesca a funcionarios especializados en la explotación que sean capaces de estudiar a fondo la situación y asesoren a los administradores sobre las repercusiones de diversos sistemas de explotación racional. Concluye declarando que son esenciales las limitaciones de la pesca que propone porque "si ésta se practica libremente, llegará el día en que no quede nada."

A generation ago fisheries were generally considered a virtually unlimited resource. Some local fisheries were occasionally depleted but fishermen could find new fields and the loss was hardly noticed. It was like the United States frontier in the 19th century, when land was there for the taking and, if you overcropped, you just moved on.

We now see a completely altered picture. Fishing fleets have increased enormously in number, size, and effectiveness. They range over the world's oceans and only the most remote and unpromising areas are unexploited. Although there is no unanimity on what exactly happened, there is no doubt that a number of important stocks of fish have been depleted to the extent of no longer being able to support an industry and that many others have been brought to a level well below the maximum sustainable yield. It is clear that we are collectively squandering and perhaps extinguishing one of the most valuable of our natural resources, and that it will be the job of governments to ensure that the fisheries of the world are properly managed and handed on unimpaired to succeeding generations.

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My experience with governments in fishing and whaling over the past 20 years is not encouraging. I have observed that their broad pattern of behavior is the same whether the country is socialist, capitalist, or in between. Governments put off restricting as long as possible; catch reduction means throwing people and ships out of work and they want to avoid the serious political problems this involves. When they do take the plunge, they dive in with eyes shut and hope that the problems will somehow disappear. At worst they hope that the industry will sort itself out and government will not get the blame for the redundancy and hardship that will inevitably follow. Occasionally the industry concerned is homogeneous and organized in a few large companies, in which case it can be left to rationalize itself. But in fisheries there are normally large numbers of units of different size and interest, and government must intervene to adjust them to a reduced catch. This requires not only hard bargaining but also thought and technical work by government people. I have not seen much sign of this so far. On the whole, the larger the government staff involved in fisheries control and administration, the less effective its impact in this field.

General Principles for Control Systems

I would like to consider some general principles for control systems. In antarctic whaling we had overall quotas from 1945 onward, starting at 16,000 blue whale units. The United States Government, following the prevailing philosophy of free competition, insisted on writing into the Convention a provision that there should be no national or individual quotas. This decision was disastrous. It had the effect of blocking conservation for about 15 years. The free competition encouraged new countries and companies to come into the industry, reducing the numbers of whales available for each expedition. Fleets struggled to get a bigger share and poured money into expanding the capacity of floating factories and building more and bigger catchers, an exercise that was self-defeating because everyone did the same. Eventually, when the need to reduce the overall quota became clear in the mid-1950s, companies were reluctant to accept reduction because they knew that any lower catch would force them out. Governments saw that unless they parted company with the principles of pure competition, the whole Convention would break down. The principle of quotas was introduced and accepted in 1958, but too late to save the industry, which collapsed a few years later.

The history of the International Whaling Commission in those crucial years shows only too clearly the folly of setting an overall quota and leaving the industry to fend for itself. It is a sad thought that in some of the 1930 seasons the quota and catcher limitation agreements made privately between the antarctic whaling companies, then mainly Norwegian and British, were a good deal more effective than the imposing international paraphernalia of the postwar International Whaling Commission.

An overall quota of fish must be the principal weapon to control a fishery, but with it there must be individual quotas for boats and plants as well, depending on the circumstances. What you are then doing, in effect, is to give particular people exclusive license to take part of the fish resource, in the same way that an oil company is allocated an offshore block or a mining company is given an ore concession. This idea applied to fisheries makes people throw up their hands in horror. But I am sure that in 20 years this will be the accepted method of running fisheries.

It is easy to declare this principle but more difficult to apply it. It is not a policy to be worked out by one harassed official in a single meeting with 100 members of the industry representing as many divergent interests. It means taking a lot of painful decisions. The door must be closed to people who still want to come into the industry (most of them voters too) while a large number of those in the industry will find themselves and their equipment redundant because there is only room to give quotas to a limited number of operators. These redundant operators must go, but they must be bought out by the government or the industry on reasonable terms.

Those operators given quotas must expect to pay a tax to their government for the privilege of harvesting the natural resource. This can be applied in the first instance to finance payments to redundant operators.

I am doubtful whether a government in managing a fishery in this way should concern itself with the use to which the fish is put. This is a perennial subject for debate in fishing countries. It is, for example, often suggested that certain types of fish "ought" to be converted into food products rather than fish meal. Operators, whether government or private, have obviously made the best economic calculations they can when they plump for fish meal rather than fish products. The "anti-fish meal" position, therefore, is not an economic one and can only be a moral posture that is unlikely to be influenced by rational arguments. Where fish resources are unlimited operators must surely be left to obtain the best economic return, and for some types and concentrations of fish this is likely to come from fish meal. Where fish resources become limited and are controlled by quotas, fish meal operations tend to become uneconomic and a larger proportion of the catch will go to food products anyway. I see no reason why governments should seek to reinforce this trend by banning fish meal operations and allowing food processors into the field instead. Such action is likely to be a misuse of economic resources and the government must then take the responsibility for scrapping existing capital investments in fish meal plants, which otherwise would continue to contribute to the economy.

Technicalities of Quota Systems

The technicalities of quota systems should, in general, reflect past performance, not operators' hopes for the future. They should be transferable, so that operators can combine or buy each other out. They should not be used to give a vested interest to the weak or inefficient who otherwise would have gone out of business. They should seek to achieve by painless methods the results that would have come about by free competition.

A commendable aspect of a quota system is that it forces rational utilization of the resource. Operators cannot concentrate on high throughput at the expense of yield. When my late Chairman first visited the antarctic in 1928 he was astonished to see Norwegian floating factories in Deception Harbour surrounded by rotting whale carcasses from which the blubber only had been stripped for processing. He questioned one of the floating factory masters on this, and the reply was: "Fishing is fishing the world over. One must grab what one can before the next man comes." This practice was later stopped by national laws and international agreement, which required full utilization of the whales. But in free competition it still looked to many companies more profitable to process a larger number of whales per day and extract only the oil, rather than to process fully a smaller number as frozen meat and meat meal as well as oil. With a quota system everyone would make the maximum use of the whales available to him.

Quotas are not, of course, the only way of restricting catch. It can be done by limiting the number of boats or length of season, or both. A limited season alone is not enough because operators will continue to build more and bigger boats as long as it is profitable to do so and the catch continues to rise. A limitation of boats has the same effect as the quota and has the advantage of being to some extent self-regulating. If there is good fish crop in any year, allowing more to be taken, the fleet will do it. But there are serious snags. If the scheme is liberally interpreted, boats compete in equipment to get a bigger share of the catch and if tightly administered the industry stagnates. The quota system combines firm control with freedom for operators to innovate.

A problem in getting fishermen to accept quotas is that the recommendations of scientists on sustainable levels of catch are often based on unconvincing evidence. In the 1950s some of the whaling people did not believe that the numbers of fin whales in the antarctic were significantly diminishing. They were not convinced by the scanty scientific evidence available — nor indeed were some of the scientists. Their attitude changed markedly when the FAO committee presented its report, which had an intellectual rigor and authority of quite a different order from anything that had gone before.

The situation of the scientists in earlier days was exemplified by Dr Cushman Murphy, who knew as much about the Humboldt current as anyone and yet advised the Peruvian Government in 1954 that any anchoveta catch above 50,000 tons a year would have disastrous effects on the balance of nature. Most scientists now would multiply Dr. Murphy's figure by 100 times before they started to worry. Fish scientists are the first to admit that their estimates, particularly on virgin stocks, are largely guesswork. As fishing develops they get more evidence and adjust their hypotheses accordingly, with a tendency for the model to get more and more complicated as they find more new factors that influence stock.

In spite of these difficulties the predictions of FAO and fish scientists generally are becoming more accurate and more respected. This trend will no doubt continue as mathematical techniques are reinforced by more detailed biological knowledge about the effects of currents, winds, foodstuffs, etc., on spawning and mortality. Fishermen are perpetual optimists — if they were not they would not be in the trade. They will not be headed off by vague prophecies of doom, but they will listen to well-grounded scientific forecasts and they prefer to be safe than sorry.

The business of fisheries management by quota or otherwise is in its infancy, so there are few case studies from which to draw lessons. This is not the place to comment on the international politics of fishing but it is clear that a fishery under the control of one nation is much more easily managed than an international one. the International Whaling Commission, which succeeded in many other ways, failed to conserve whale stocks, partly because of its exclusion of national quotas but mainly because the countries concerned were unable to reach effective agreements. Peru is able to control her fishery because it is a national one; it would have been more complicated if fleets of several nations had been sharing the same resource.

The Peruvian Government has always been conscious of the need to control the anchoveta fishery. It has had a closed season and catch limitation for many years. More recently there has been a check on building or extending plants and increasing fleets. But the limitation on plants has had many exceptions and the ceiling placed on the number of boats is recent. Consequently, we have a position rather like antarctic whaling in the 1950s. Operators who could afford to do so have increased plant and boat capacity to get a bigger share of the catch and have reduced the length of season by taking the overall quota in a shorter time. A quota of 10 million tons of fish can now be taken in 80–100 days. This is an extravagant way of catching fish. The costs of having twice as much equipment as necessary lying idle for two-thirds of the year are enormous. They make the industry vulnerable to any drop in the price of fish meal. While the Peruvian Government is fully conscious of this position, which can only be corrected by removing about half the plants and boats from the industry, it is reluctant to take action because, in a country where jobs are scarce, this would throw a lot of fishermen and plant workers on to the street.

Peru has applied two principles interesting for fisheries management. One is to tax the companies on the meal they produce regardless of profitability (this was previously an export tax, but has now quite properly become a resource tax). The other is to set minimum requirements for efficiency in processing. This has contributed to raising the yield and may be necessary for a fishery that is technically underdeveloped. Otherwise a quota system and a resource tax will tend to push the operator to make the best use of his fish without further intervention.

The South African fish meal industry was from the start organized by the Government with plant quotas and limited entry. This has been successful and a prosperous industry has grown up under State protection. The policy was modified with unfortunate results when two South African companies were allowed to operate floating factories on the same stocks outside the 12-mile limit. This has now been stopped. Largely because of its quota system, the South African fish meal and canning industry is the most efficient in the world in its utilization of fish. I believe also that the stability of the industry has fostered the admirable Fishing Industry Research Institute, which in its turn has contributed greatly to the companies' performance.

Fish meal industries consist of a number of similar units and so are fairly easy to regulate. Where there are different types of fishing and processing, as in the eastern Canada herring fishery, the difficulties of regulation become considerable. There are clashes of interest between the large and the small operators and between those well established and those just starting, and between plants without boats (which need assured supplies of fish) and boats without plants (which need to be free to sell in the best market). There can be no simple rules in deciding allocations between such interests. This must normally be done on the basis of past performance, adding allowances to cover new equipment already ordered but not yet brought into operation. If the government goes significantly away from this principle and discriminates in favor of certain types of fishing or processing or makes allocation for people not in the industry, then it must be prepared to provide some compensation for those whose economic position is affected by this action.

Advice to Administrators

I offer some advice to fisheries ministers and their departments. They should try to be more long-sighted than the industries they control. Governments never take action early enough. A learned friend in fisheries administration once propounded his own law of conservation, which is roughly that "no conservation measures are ever applied until after the species which they are intended to protect has been exterminated." The time to institute control is when a fishery is reaching its peak, not when it has passed the top and is going downhill. This is of course the most difficult time. Everyone is enthusiastic, there is gold-rush fever in the air, aided and abetted by government agencies whose job it is to promote new investment by lavish grants and loans. Even when the euphoria has gone and it has become manifest that there are too many boats and plants in the industry, there is a long lag before action is taken. It takes a degree of intellectual flexibility, which most of us cannot approach, to switch from encouraging people to invest to preventing people from investing. Everyone knows examples of fisheries that have been ruined by over enthusiastic government promotions, whether through private industry or state plans.

If you are encouraging a new fishery, a cardinal rule is: start small and let it develop step by step. It is cheaper to wait a year or two and risk letting some fish go than to let everything rip and then be faced with the problems of a huge bankrupt industry. Expansion is exhilarating; contraction is painful.

Another trap for governments is laid by their hunger for tax money. They have to balance national budgets or want to raise money for other purposes, so they defer restricting a catch, hoping that this year it will recover and their finances will be salvaged. Instead of raising money from the industry this policy ends in disaster and they have to bail out the industry with subsidies. If they looked further ahead they would realize that by rational management they could eventually collect far more in taxes from the industry than before.

In the troubled field of international fishery negotiations industry expects government to be firm in defending its interests and in securing a fair share of the resource available. There is some tendency for government negotiators to think of fisheries conferences as scientific symposia at which international reason will harmonize to provide a logical solution. This is fine if everyone is playing the game by these rules, but less satisfactory if some of the countries are playing by different rules. In fact, a fisheries conference on quotas is very like any other international political negotiation, very similar to, say, discussions for a treaty on atomic disarmament. Every country aims to sacrifice as little as possible and marshals its arguments accordingly. Scientists, however impartial they try to be, are inevitably enlisted as national protagonists, and the outcome reflects mainly the power relation between the countries concerned. Any agreement on measures is only the first stage and it may be far more difficult to ensure that the agreement is observed. Any government fisheries negotiator who enters the conference room without full appreciation of these factors risks being stripped and robbed before he realizes what is happening.

I also advise government negotiators not to take too high a moral line about the shortcomings in conservation of other countries. Nothing gives greater joy to the malicious than the sight of an arch-conservationist fisheries minister being forced to swallow all his principles under pressure from his industry, which his high-minded policies are threatening to wipe out.

Any fisheries management policy is bound to be complicated. It cannot just be worked out in a government department and imposed on industry. Industry must be consulted closely and negotiated with, for it is only in this way that government can assess all the interests involved and the relative strengths of the units in the industry. This applies to international as well as national management. If industry is consulted beforehand the government negotiator at least knows what will or will not have the blessing of the industry and he will frame his policy accordingly. It is impossible for industry to make a practical, valuable contribution, even if it is invited to the conference itself, if the issues have not been thrashed out beforehand. National management policy will inevitably take a long time to work out, with endless meetings in smoke-filled rooms. Jobs and investments are at stake and any government that gives ear to the welfare of its citizens must sort the problems out as far as possible by consent.

My final suggestion is that governments should fortify themselves for fisheries management by engaging one or two people who specialize in this. The technical and economic side is highly complicated and cannot just be thrown into the laps of overworked fisheries administrators. For a start fisheries departments should make sure that they have full catch statistics. Some do not even have those. Such matters as type and size of boats, number and capacity of plants, economic returns of different operating units, trends in development, and effects of different quota systems are all matters that can be studied and analyzed in detail by a specialist who could, before the haggling with industry begins, brief his chiefs on the implications of alternative management policies. I would like to see FAO take the lead in this, and have people with skill in this sphere made available to governments who did not want to do the work themselves. FAO has already provided advice of this sort to Peru.

These ideas must face the criticism that their implementation would place the fishing industry in a bureaucratic straightjacket. But free fish means eventually no fish. Fish resources must be allocated like any other natural resource. I believe that control systems, although inevitably complicated, can be refined and simplified as we get more knowledge and experience.

Impact of Technical Development on the Problems and Opportunities in World Fisheries and Their Management[1]

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EDDIE, G. C., AND A. D. INSULL. 1973. Impact of technical development on the problems and opportunities in world fisheries and their management. J. Fish. Res. Board Can. 30: 2490–2495.

In the past quarter-century, fisheries technology has developed to such an extent that the failure of a particular fish stock is not necessarily the unmitigated economic and social disaster it would have been in former times. The development of more flexible, powerful, and controllable systems of production, including marine fish farming, and greater versatility in processing and marketing, mean that the maintenance and improvement of the productivity of the oceans as a whole, in terms of raw protein and oil, are beginning to be of more importance than the conservation of local wild stocks. While failure of a stock may no longer be disastrous, there are other risks, some of them man-made, which may be more serious. Good management must take account of these other risks as well as have regard to the husbanding of the resource.

Management must, moreover, be directed to practical objectives of a social, economic, and commercial nature. The degree of attention that should be paid to such matters as capital investment, manpower, training, and education, technical development, and marketing varies according to local circumstances. In many fisheries a lower level of exploitation might be possible if the catch were better utilized, and this would seldom conflict with the objectives of the fishing enterprises concerned. In the past too much attention has been focused on catching operations.

Good management must also have due regard to the preservation, processing, and distribution of the catch as well as to the proper use of equipment, manpower, and other resources.

It is not easy to devise systems of management that reconcile all the requirements and all the objectives of each of the participating enterprises in a fishery in a practical way. The establishment by a state of jurisdiction over an artificially delimited expanse of ocean, for example, may not necessarily simplify the real problems of management of the fisheries within that area. Greater emphasis on other measures and a partial redeployment of the resources devoted to fisheries protection and fisheries research might lead more quickly than present policies to the establishment of effective methods of exploiting the productivity of the oceans at a higher level.

The present assumptions and bases for fisheries management and control throughout the world are questioned, and a new "world approach" is proposed to attain maximum utilization of stocks including productive use of large quantities of "trash fish" and of unfamiliar species.

Au cours de ce dernier quart de siècle, la technologie des pêches a évolué à tel point que l'épuisement d'un stock donné de poissons ne constitue plus nécessairement l'incontestable catastrophe économique et sociale qu'elle aurait été jadis. La mise au point de sytsèmes de production souples, efficaces et contrôlables (y compris la pisciculture marine), ainsi que la plus grande polyvalence de la transformation et de la commercialisation, dénotent que le maintien et l'amélioration de la productivité des océans dans leur ensemble, sous l'angle des protéines et de l'huile comestibles, commencent à revêtir plus d'importance que la conservation des stocks halieutiques naturels locaux. Si l'épuisement d'un stock peut ne plus constituer une catastrophe, il existe d'autres dangers, dont certains dus à l'intervention de l'homme, qui risquent d'être plus graves. Tout aménagement efficace doit tenir compte de ces autres risques et veiller à la bonne gestion des ressources.

L'aménagement doit en outre viser des objectifs sociaux, économiques et commerciaux concrets. Le degré d'attention à porter à des facteurs tels que les investissements de capitaux, la main-d'oeuvre, la formation et l'enseignement, le développement technique et la commercialisation, varie en fonction des circonstances locales. C'est ainsi que nombre de pêcheries pourraient avoir un niveau d'exploitation moindre si les prises étaient mieux utilisées, sans pour autant compromettre, ou du moins rarement, les objectifs des entreprises de pêche en cause. Par le passé, en effet, on s'est trop attaché aux captures proprement dites.

Un bon aménagement doit aussi tenir compte de la conservation, de la transformation et de la distribution des prises, et veiller à l'utilisation convenable du matériel, de la main-d'oeuvre et des autres ressources.

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

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Il est difficile de concevoir, de façon pratique, des systèmes d'aménagement qui concilient tous les besoins et tous les objectifs de chacun des services mis en jeu par une pêcherie. C'est ainsi que l'établissement, par un Etat, d'une juridiction sur une étendue d'océan arbitrairement délimitée ne simplifiera pas nécessairement les problèmes réels d'aménagement des pêches dans cette zone. Il se peut qu'en mettant davantage l'accent sur d'autres mesures et qu'en redéployant partie des ressources consacrées à la protection des pêches et à la recherche halieutique on parvienne plus rapidement qu'avec l'aide des politiques actuelles à mettre au point des méthodes efficaces pour mieux exploiter la productivité des océans.

On doute désormais du bien-fondé des hypothèses et bases actuelles pour l'aménagement et le contrôle des pêches dans le monde et l'on propose l'adoption d'une nouvelle "optique" mondiale pour l'utilisation maximale des stocks, y compris l'exploitation productive des grandes quantités de "poissons de rebut" et des espèces peu familières.

En los últimos 25 años la tecnología pesquera se ha perfeccionado en tal medida que la ausencia de una determinada población de peces no constituye el desastre social y económico que hubiera sido en otros tiempos. El perfeccionamiento de sistemas de producción más flexibles, potentes y sujetos a verificación, incluyendo la piscicultura marina y una mayor diversidad en los métodos de elaboración y de mercadeo, significa que el mantenimiento y mejora de la productividad de los océanos considerados en conjunto, en función de las proteínas y aceites, están empezando a tener más importancia que la conservación de especies locales. Aunque la ausencia de una población ya no tiene carácter desastroso existen otros riesgos causados por el hombre que pueden ser más graves. Una buena reglamentación debe considerar estos otros riesgos así como ocuparse de la economía del recurso.

Además, la reglamentación debe encaminarse a objetivos prácticos de naturaleza social, económica y comercial. El grado de atención que ha de prestarse a asuntos como la inversión de capital, mano de obra, enseñanza, progreso técnico y mercadeo, varía de acuerdo con las circunstancias locales. En muchas pesquerías podría reducirse la explotación si las capturas se aprovecharan mejor y ello pocas veces puede entrar en conflicto con los objetivos de las empresas pesqueras interesadas. En lo pasado, se ha prestado mucha atención a las operaciones de captura.

Una buena reglamentación también debe considerar la conservación, elaboración y distribución de las capturas así como el adecuado empleo del equipo, mano de obra y otros recursos.

No es fácil prever sistemas de reglamentación que aunen de una manera práctica todas las necesidades y todos los objetivos de cada una de las empresas que participan en la pesca. La institución por un estado de una jurisdicción artificialmente delimitada en una zona del océano, por ejemplo, no significa que se simplifiquen los problemas reales de la reglamentación de la pesca dentro de dicha zona. El poner más empeño en otras medidas y una redistribución parcial de los recursos que se dedican a la protección y a la investigación pesqueras, podría llevar más rápidamente que lo hacen las actuales políticas a la institución de métodos efectivos para explotar más la productividad de los océanos.

Los actuales supuestos y los fundamentos para la reglamentación y control de la pesca en todo el mundo quedan en tela de juicio y se propone un nuevo "método mundial" para obtener la máxima utilización de las poblaciones, incluyendo el uso productivo de grandes cantidades de morralla y de especies desconocidas.

FISH population dynamics and fisheries management have tended to assume that food and fisheries technology are relatively stagnant. Indeed, they were in the first half of the twentieth century in many of the most important fisheries, but this is no longer so. It has also usually been assumed that market requirements are unchanging and unchangeable; thanks to modern marketing techniques, this too is no longer so. The demand for conventional fisheries products may some day be supplied to an increasing extent by marine fish farming. New products and new opportunities, developed by the food technologists, may in future make the fishing enterprise much less dependent on the availability of particular sizes and species of fish, and fisheries may become more and more a source of raw protein for further processing. The total utilizable yield in terms of human food might then be much higher.

It is probably fair to say that one of the gravest concerns of those engaged in fisheries — particularly those who fish for certain species of tuna and those engaged in the North Atlantic and a number of areas in the Pacific — is the pressure of fishing effort, particularly against selected species, causing overfishing or alleged overfishing. As a consequence, attention is becoming increasingly focussed on arguments relating to the extension of fishing limits, perhaps extending for hundreds of miles, so that the world's fishermen are rapidly being put into one of two groups: those who believe their self interest lies in a major extension of fishing limits by their government and those who fear that their earnings would be reduced or curtailed should fishing limits be extended generally.

In this paper we do not enter into a discussion about fishing limits per se but, taking into account the current concern with fisheries management which has become closely connected with discussions about fishing limits, raise some questions about our present approach to fisheries management.

Our starting point is to draw attention to developments, particularly rapid in the last 10 years, in the technology of the fishing and food industries.

Developments in Technology

A fundamental effect of the development of technology has been to enable men to become independent of their local environment. In fisheries, this has been true for hundreds of years. The British, for example, were fishing off Iceland at least 300 years ago, while the Portuguese and French salt cod fleets operating on the Grand Banks also have a long tradition behind them. Recently, however, the pace has accelerated. French tuna clippers are operating in the Pacific and Indian Oceans and Japanese freezer trawlers fish off Newfoundland. It is now possible to catch fish in almost any part of the ocean at almost any season of the year and bring the catch to the consuming country, however distant, in acceptable condition. In the last few years, too, there has been an acceleration in the pace of gear development and refinements in fish-finding techniques, so that the fisherman is able to catch more fish. Nor have all developments been confined to the hunting aspect of the industry: in recent years we have seen considerable advances in the development of a new technology, that of marine fish farming. These decisive technical developments have been so recent that the full implications are not yet always realized by those concerned with fisheries management.

This recent improvement in our ability to exploit the oceans is now beginning to be complemented by a rapidly growing ability to make acceptable products from raw material that was hitherto difficult to utilize and to make standard and familiar food products from a variety of sources of raw protein.

New Approach to Fish Resources

If the premise is accepted that technological developments have proceeded to the point outlined above, we may question whether the concept of regulating a local stock of fish to produce an equilibrium (insofar as this is possible in the face of fluctuations and changes of natural origin in the hydrographic and biological conditions) may be the only valid policy, as it would be in an isolated lake containing a single edible stock. Thus, the question is whether, now that we have the technical means to do so, there is any fundamental biological objection to attacking concentrations of utilizable species as hard as possible and for as long as it is economically beneficial to do so, and then to switch the attack elsewhere? We are not suggesting that there should be no control of international fishing effort, but that the criteria which are currently applied to regulatory measures might be radically different to those which are presently applied.

There would be, of course, major political problems inherent in such action, and substantial marketing difficulties. These factors are discussed briefly later, but recognition for what they are would be a major step forward in the philosophy of fisheries development.

The occurrence of a scarcity of fish on a particular local ground is not, or need not be, the economic and social disaster that it was in former times. The major risks run by a modern fishing enterprise are different. They include fierce competition in the market place from the products of modern agriculture, such as the broiler chicken, mass-produced in controlled conditions, using highly efficient methods and backed by strong research and marketing. Other major risks include the growing scarcity of men able and willing to go to sea for any price, and may include growing competition for this scarce labor and for sea-room, e.g. by the offshore oil industry, with a risk of major pollution. Perhaps the most constant, ever-present risk is that of unilateral or multilateral extensions of national fisheries limits on the high seas. For a fishing enterprise well equipped by modern standards, only a general scarcity of all fish on an ocean-wide basis may be of greater potential gravity than those other risks. So, if economic and social disaster to a given community through failure of local stocks is no longer inevitable, we should perhaps put less administrative and scientific effort into monitoring and conserving local fisheries than was thought necessary hitherto, especially where the stocks are migratory or interrelated to those in other fisheries, and more effort into the problem of getting the maximum amount of food out of the oceans as a whole. We might, for instance, reexamine our attitudes to overfishing and to deployment and control of effort.

POSSIBLE BIOLOGICAL OBJECTIONS TO "INTENSIVE FISHING"

Intensive fishing, or fishing past the point of maximum sustainable yield, is not likely to be decisive for survival of the species, at least for many of the common species of fish. For instance, in theory the entire cod stock of the North Atlantic could be replenished in one generation from about 30 surviving adults, given 100% survival from the egg. If more than one generation is allowed for replenishment, the necessary percentage survival presumably drops dramatically. This, of course, begs the question of the minimum congregation of individuals necessary for spawning to occur and perhaps this is one of the biological questions on which more information than we have at present might be enlightening.

Practical commercial fishermen and vessel owners talk in terms of overfishing when fish of marketable size and species begin to be so scarce that costs of production are likely to equal or exceed earnings. Technical development can reduce costs per unit production either by improvements in catching capability (e.g. fishing at greater depth, or by new or improved gear) or by improved efficiency (e.g. by reduced requirements for manpower or fuel). Costs of production also depend upon the standards of living enjoyed by the fishing community, although earnings may depend on the market they supply, over which they may have much or little control. A fishing community using obsolete technology or poor in skill but demanding a high standard of living — and there are such — will cry "overfishing" sooner than one with a poor standard of living, or greater skills, or better equipment. Similarly, a fishing community tied to low market prices but demanding a high standard of living, will cry "overfishing" sooner than a community having better control of the market. In some instances a weak market in one country can affect world prices for a particular variety or product. There is a danger that fisheries are legislated for and managed by regulation of catch and effort to meet the wishes of such communities without, at the same time, making provision for the programs of technical development, education and training, or market development, which alone will provide a real solution to their problems.

It seems to be reasonably well established that in some fisheries the same catch could be produced using fewer vessels, and this could have the same sort of effect on costs and earnings as technical development. Since the world's oceans as a whole are underfished, it is well worthwhile examining the possibility of diversion of such surplus effort on to other stocks, so as to increase production with a minimum of new capital investment. The financial, commercial, and technical problems would be formidable and would require the goodwill and offices of governments and UN Agencies; any success in overcoming them would not only serve UN objectives but also be a step toward proper management of the world's oceans on behalf of all.

Optimization of Useful Catch

In such a system of management, the object of regulations such as mesh sizes, closed seasons and the like would be to optimize the useful harvest within safe biological limits, rather than to serve the demands of traditional markets for certain sizes and species at costs of production acceptable to communities with particular technical, social and economic backgrounds.

If the local population of a given species is heavily reduced, the biological niche that it occupies may be taken over by some other, less desirable species. The question here is whether the usurping species should be less edible or a less efficient converter of nutrients. If the problems in change of species are merely those of social preference and conservatism, they can in course of time be solved by modern food technology and marketing. The marketing difficulties inherent in switching, say, from cod to saithe, and then perhaps to redfish and whiting and hake and pollock may at first seem daunting. Perhaps this is because we tend to regard fish as a product in its own right rather than a basic source of protein capable of further development and added value. The introduction of fish sticks into the North American market 20 years ago is the only outstanding achievement in the marketing of fish products. For many years the abundance and availability of cod and its historical importance was such that, although other species were suitable for fish stick manufacture, cod was mainly used. Only in the last year or so have the vast resources of Pacific pollock been tapped to supply the market previously monopolized by cod.

While the fish stick represents the only break-through in the marketing of fish, the number of convenience-food products which have been derived from it have already gained a major share of the rapidly expanding convenience food market in the developed economies. And the probability is that we have only just begun to tap the potential of this market in the long term.

Availability of Supplies

Contrary to established opinion, there are grounds for optimism so far as the availability of supplies is concerned. Modern methods of presentation and marketing have brought us to the point where the exact species is of less importance than hitherto, and modern food technology has made it possible to produce acceptable fillet blocks, portions and sticks, "surimi" and so on, from a variety of species. In the not too distant future, consumers who insist on large, live or chilled fresh fish may be best catered for by fish raised in captivity in a marine fish farm.

That marine fish farming can play this role is well within the limits of probability although the extent of its role is open to speculation. It may be, however, that marine fish farming will become of central importance to the fish industry. The finite limit on what we can harvest from the oceans is well above the present total and the extent to which we can exploit the stocks depends on the economics of concentrating and harvesting the various species. The amount we can take from the sea may also depend on how far man can, and should, replace the predators, such as cod for example, and harvest the sprats, sand eels, and capelin. Some predators might be made available more efficiently by farming where better food conversion rates than in nature can be obtained from shortened food chains.

What should be done depends on questions about the ecological roles of the various commercially useful marine fishes, and of their eggs and larvae. Control of total catch on a less narrow basis than that of local geographical stocks of traditionally acceptable species must also depend to a large extent on the ability to identify what stocks and what geographical areas or bodies of water constitute, for practical purposes, more or less self-contained systems. It also depends on the degree of interaction within these systems between species and between local substocks, especialy as regards replenishment and substitution. The questions of whether one species is usurping the niche of another (and whether this matters in the sense of good management), and whether stocks have been brought below the level of the minimum congregation necessary for successful spawning are more fundamental and more important than the study of the dynamics of exploited local substocks of traditionally-acceptable species. At least this is the case where advantage can be taken of modern technology in vessel design and fishing techniques, and of modern methods of preservation, processing, presentation, and marketing to reduce dependence on a few traditional stocks.

The objective of fisheries management and control then would be to ensure that large areas of ocean, each corresponding to the entire geographical range of all interrelated and overlapping substocks and species, are exploited at or near, but not beyond, the maximum sustainable yield. This is in contrast to the present attempts to ensure the survival of local substocks of only some of those species that happen to be regarded at present as marketable. This is a policy that is not entirely sound in the scientific sense and leaves other species and areas unprotected. It may be expected that coastal communities dependent on the abundance of local stocks would be opposed to this concept of fisheries management. The traditional vested interests in such communities tend to be strong, and distinguished more often than not by their resistance to improved efficiency in fishing. Also, such communities tend to be situated in economically deprived regions where fishing is one of the main springs of the local economy.

Such communities may exert considerable political pressures to bring about national legislation to isolate and regulate the intensity of fishing on substocks, or even on stocks which are dependent on other species in a wider geographical area. But, given a new approach to fisheries management consistent with the changes in technology which have taken place, such an attempt results in a total yield substantially less than it might be.

Improved Use of Catch

The contribution of the food technologist to the improved utilization of the catch has already been great but much more could be done. A recent example is the work of Petersen and others at the Copenhagen fish technology laboratory on the losses in weight of catches in the North Sea industrial fishery during storage in the holds of catching vessels. This, in a relatively cool temperate climate zone and in wooden vessels making voyages of only a few days, amounts to as much as one-twelfth of the annual catch. It can be almost entirely prevented by use of ice, which would result in a higher yield and quality of the fish meal, and an increased throughput of the fish meal plant. Thus, fishing mortality might be reduced by about 10% for the same production of meal in terms of nutritional value, with resulting economic gain. The cost of ice is little in relation to this gain. The same 10% or so reduction of fishing mortality by measures such as mesh size regulations would, in contrast, add to costs, while closed areas or seasons would have similar results to those in the Pacific halibut fishery. It has been estimated that the avoidable losses in the world's fisheries devoted to meal and oil production amount to 2.5 million tons a year landed weight.

Most of the herring caught in the North Atlantic in the last 10 years or so has been used for production of meal and oil. Yet this fish is to many people one of the most palatable, and it can be presented to the consumer in a variety of forms. It is at present scarce in the Eastern Atlantic, apparently because of its overexploitation for reduction, mainly by the Scandinavian countries. Because of this scarcity, the Canadians have been saving a proportion of their catch for human consumption instead of most of it going to meal and oil. The point in the context of the present paper was well made by Iles: if herring is caught for human consumption and fetches 10 cents a pound at the vessel's side, only one-fifth as much has to be taken to give the same number of fishermen the same money income as if it is caught for reduction at 2 cents a pound.

It behooves those nations possessing the necessary technical knowledge and resources to make the best possible use of their catches: that is to say, to turn them into high-value products, thus making it less necessary to catch so much, reducing the pressure on stocks. The development of the large purse seines and midwater trawls, which produce spectacular catches, has made the problems of handling, preservation and processing greater than before. More effort should go, therefore, to the development of equipment and techniques for the effective handling of these bulk catches in such a way as to prevent spoilage. Perhaps there should also be renewed effort to develop methods of capture that produce a more even flow of fish on board the catching vessel. Such developments would result in better products, less wastage and spoilage, hence reduced fishing mortality for a given income per head employed and for every pound of edible protein produced.

REDUCTION OF WASTE

Spoilage, wastage, and loss of value arise from many causes. The amount of care and skill exercised in the handling, preservation, and processing of the catch, from its arrival on board until the final product reaches the consumer, varies greatly from fishery to fishery, from community to community, and from nation to nation. Some of the richest and most advanced nations are by no means good performers in this respect, nor are some communities which have a long tradition of sea fishing. In the coastal trap fishery of Newfoundland, for example, cod in poor physiological condition are trapped in warm, shallow water and can exhibit marked deterioration in quality by the time they can be harvested and chilled. It is at least worth asking whether this trap fishery should be abandoned and the cod caught offshore in better condition.

Yet another aspect of wastage is the rejection of fish, i.e. throwing them overboard in a dead or dying condition, because they are not readily acceptable on the local market. The Canadians do not exploit skates, and reject those they catch, as the British used to reject redfish, queen scallops, and *Nephrops*.

On a happier note, the availability of mechanical gutting machines has made it possible to retain a higher proportion of the catch in circumstances where fishing is heavy. Formerly a proportion of the catch would be rejected because the fishermen could only select and gut the larger fish. The advent of deboning machines also allows the utilization of small fish and unwanted species if acceptable products can be developed. The use of such machines also allow a less negative policy toward the retention of legally undersized fish than obtained in some countries — always provided the mesh or hook sizes employed are themselves legal. International agreements to retain, process, and preserve unwanted species for export to countries where they will be readily consumed is something worth pursuing. Yet another possibility is an international agreement for each nation to use its best efforts to carry out product development and marketing trials of underprized species whose capture is unavoidable by present methods and which would otherwise go for reduction or be wasted.

Education and Training

The aims of good fishery management also call for better education and training of officers and crews of vessels, and of managers and operatives of processing plants, cold stores, and distributive systems, in the subjects of handling, preservation, and processing of the catch. Too much effort may be devoted to the traditional activities associated with fishery management, including fisheries protection in the orthodox sense. Greater stress on quality control and inspection of catches might do more good. Given the relatively poor state of applicable knowledge in the field of commercial fisheries biology compared with that in food technology, such a diversion of effort would be highly cost-effective from the point of view of conservation, at least for some years to come.

There is no doubt that in fishery management and development more consideration should be given to effective utilization of the catch, if only with the objective of husbanding the resource and making exploitation more efficient in terms of reduced fishing mortality per pound of fish on the consumer's plate or per dollar in the fisherman's pocket.

Marketing

Even if the new approach to management and control suggested was fully adopted, the requirements of the market would remain supreme, and switching from one species to another or even to another stock of the same species might raise short-term problems ranging from the difficult to the insurmountable. To that extent, it may have to be temporarily accepted that particular fishing fleets, however versatile and well equipped, may remain tied to particular stocks for the life of existing ships and other major plant.

Conclusion

Perhaps the job of estimating the size and possible yields of resources and the effects of exploiting them should be left to sonar engineers, gear technologists, and operations research mathematicians, because commercial fisheries biologists are comparatively scarce and might be more effectively employed in trying to answer more fundamental scientific questions. We have tried to indicate the nature of these questions which, speaking generally, would be aimed at stating more precisely, and in sufficient quantitative detail to be useful for management purposes, the fundamental biological boundary conditions and limiting factors of marine fishery resources. This might, for example, give some indication of whether the policy of steady state continuous exploitation of each stock is as necessary or right as it was when most fishing communities were ill-equipped and served such inflexible markets that they depended on the continued existence of one or two local substocks.

It is desirable to determine what stocks can be considered closed systems for legal, administrative, and political as well as scientific reasons. It is not clear what proportion of stocks would constitute independent closed systems within national fishery limits, even if these were extended. Except for oceanic islands and countries with long north–south coastlines, the answer may be few or none. So the real reason for extending fishery limits may be reduced to that of national economic self-interest.

When a coastal state claims jurisdiction over the adjacent fisheries, whatever the extent and whatever the avowed reasons, it should satisfy the rest of the world on two counts: first, that it is able to exploit and utilize those resources to the full, or is willing to let others help it to do so, and will not place restrictions on the technology employed in deference to the wishes of unprogressive local communities; second, that it (and its colaborators, if any) are capable of handling, processing and preserving the catch well enough to justify the state's exclusive right to dispose of those resources.

Interaction Between Fishery Management and Environmental Protection[1]

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Assessment of the need to take account of fishery and environmental parameters in management depends on the precision with which it is possible to predict fishery yields from fishery and environmental data. Earlier attempts to demonstrate simple correlations of yield with various fishing and environmental indices were frustrated by variability in statistical data, poor definition of oceanographic and population systems, and ignorance of the responsible mechanisms. Recent research has overcome some of these difficulties. The results support earlier hypotheses that environmental fluctuations are major factors controlling year-class success. There is also evidence for strong density-dependence of survival of larval fishes, and of growth in juveniles and adults, all of which tend to stabilize population production under a wide range of environmental and fishery "stresses." There is recent evidence, however, that in some populations, effects of the recent and highest sustained rates of fishing have exceeded the "adaptative" capacity of the production-compensating mechanisms so that the carrying capacity of the environment is now unsaturated. There is thus a higher probability that a "normal" succession of "poor" years will lead to fishery collapse. While we do not understand why the effects show in certain species and areas and not in others that are equally heavily fished, there can be little doubt of the reality of these symptoms of interaction of fishing and environmental effects.

The main mechanism controlling fishery productivity fluctuations within areas appears to be the degree of vertical mixing in oceanographic systems, with the associated nitrogen supplies and food resources for the early life-history stages of fishes. There still exist major unexplained differences between areas in the structure of the producing communities and the yields from them. Explanation will require detailed study of particular areas. In parts of the Northwest Atlantic, it appears that the control of production is geographically sited along the coastlines, where the risk of concentrations of pollutants also appears highest. In other areas, such as the Northeast Atlantic the oceanographic processes underlying production may be different.

Assessment of the risk of pollution concentration, and its importance in reducing density-dependent compensatory production responses, is still frustrated by high-frequency variability in samples of both biological and physical parameters. Recent studies have demonstrated that this variability may be associated with particular types of generating mechanisms and suggest means for interpreting it. Further research in this area is required before meaningful environmental and biological monitoring programs can be undertaken.

Recent knowledge of natural variability, and its interaction with density-dependent mechanisms controlling production, implies that a new approach involving "discontinuous" models appears necessary to prediction of ecosystem responses to fishing and pollution. But whatever their precise form, it is now clear that both the predictive models and the management systems built upon them, must necessarily take account of both fishing and environmental quality parameters if the management is to be effective.

Les paramètres halieutiques et écologiques à faire entrer en ligne de compte dans l'aménagement ne peuvent être évalués qu'en fonction de la précision avec laquelle les données sur la pêche et le milieu permettent de prévoir les rendements des pêcheries. Les tentatives faites par le passé pour établir des corrélations simples entre le rendement et les divers indices halieutiques et écologiques ont échoué à cause de la variabilité des données statistiques, de la définition médiocre des systèmes océanographiques et ichtyques, et de l'ignorance des mécanismes en jeu. Les recherches récentes ont permis de surmonter certaines de ces difficultés. Les résultats confirment les hypothèses précédentes selon lesquelles les fluctuations de l'environnement jouent un grand rôle dans l'abondance de la classe d'âge. On constate également que la survie des poissons à l'état larvaire et la croissance des jeunes et adultes son étroitement associées à la densité, tout ceci tendant à stabiliser la production de la population sous l'effet des "agressions" très diverses exercées par l'environnement et la pêche. Toutefois, il a été démontré récemment que dans certaines populations, l'intensité extrême et soutenue des opérations de pêche ayant excédé la capacité "d'adaptation" des mécanismes compensateurs de production, il n'y a plus saturation de la charge biotique utile de l'environnement. Aussi est il plus probable

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qu'une série "normale" d'années "maigres" aboutira à l'épuisement de la pêcherie. Bien que l'on ne s'explique pas pourquoi ces effets se manifestent pour certaines espèces et zones, et non pour d'autres, tout aussi fortement exploitées, il n'est guère douteux qu'il y a interpendance entre la pêche et l'environnement.

Il semble que, à l'intérieur des zones, les fluctuations de la productivité halieutique dépendent principalement du degré de mixage vertical des systèmes océanographiques, et de leurs disponibilités en azote et ressources alimentaires pour les poissons aux premiers stades de leur existence. De grandes différences, encore inexpliquées, existent entre les zones dans la structure des communautés productrices et de leurs rendements. L'explication de ces différences exigera une étude détaillée de chaque zone. Dans certaines parties de l'Atlantique Nord-Ouest, il semble que le contrôle de la production s'opère géographiquement le long des côtes, où se présentent aussi les plus grands risques de concentration de polluants. Dans d'autres zones, comme l'Atlantique Nord-Est, il se peut que les processus océanographiques influant sur la production soient différents.

Etant donné la forte variabilité dans les échantillons de paramètres tant biologiques que physiques, il est encore impossible d'évaluer le risque de concentration de polluants et la mesure dans laquelle il entrove les réactions compensatrices de production liées à la densité. De récentes études démontrent que cette variabilité peut être associée à des types particuliers de mécanismes générateurs et proposent des moyens pour l'interpréter. De plus amples recherches s'imposent dans ce domaine avant de pouvoir entreprendre des programmes sérieux de surveillance écologique et biologique.

D'après les données récentes sur la variabilité naturelle et son interaction avec les mécanismes de contrôle de la production tributaires de la densité, il semble falloir adopter une nouvelle approche, mettant en jeu des modèles "discontinus", pour prévoir les réactions de l'écosystème à la pêche et à la pollution. Quelle que soit leur forme exacte, il est clair désormais que les modèles de prévision tout comme les systèmes d'aménagement fondés sur lesdites prévisions, doivent nécessairement tenir compte des paramètres sur la pêche et la qualité de l'environnement, si l'on veut que l'aménagement soit efficace.

La necesidad de tener en cuenta los parámetros pesqueros y ambientales a la hora de preparar medidas reguladoras depende de la precisión con que sea posible predecir el rendimiento pesquero a partir de datos pesqueros y ambientales. Los intentos hechos anteriormente para demostrar una relación directa entre rendimientos y los diversos índices pesqueros y ambientales se vieron frustrados por la variabilidad de los datos estadísticos, la mala definición de los sistemas oceanográficos y de población, y la ignorancia de los mecanismos determinantes. Las investigaciones recientes han superado algunos de estos obstáculos. Los resultados obtenidos confirman las hipótesis hechas anteriormente de que las fluctuaciones ambientales son factores importantes que influyen en el éxito de las clases anuales. Hay también indicios que demuestran una gran influencia de la densidad en la supervivencia de las larvas de peces y en el crecimiento de las formas juveniles y adultas, lo que tiende a estabilizar la producción de la población bajo una vasta gama de tensiones ambientales y pesqueras. De todas formas, en algunas poblaciones se ha podido comprobar que los efectos de índices sostenidos de pesca más elevados han sido superiores a la capacidad de adaptación de los mecanismos compensadores de la producción, con lo que la capacidad del medio ambiente se encuentra en la actualidad insaturada. Hay, pues, mayor probabilidad de que una sucesión normal de años "de escasez" dé lugar a un colapso de la pesquería. Aunque aún no entendemos por qué los efectos aparecen en algunas especies y áreas y no en otras sometidas a una explotación igualmente intensa, apenas es posible dudar de la realidad de estos síntomas, que demuestran una relación entre el esfuerzo de pesca y los efectos ambientales.

Los principales mecanismos que controlan las fluctuaciones de la productividad pesquera dentro de algunas zonas son el grado de mezola vertical de los sistemas oceanográficos, con el correspondiente abastecimiento de nitrógeno y recursos alimenticios para las primeras fases vitales de los peces. Existen aún grandes diferencias inexplicadas entre una zona y otra en lo relativo a la estructura de las comunidades productoras y el rendimiento de las mismas. Para explicarlas será necesario estudiar detalladamente algunas zonas concretas. En determinadas zonas del Atlántico Noroeste, el control de la producción se verifica geográficamente a lo largo de las costas, donde el peligro de concentración de contaminantes es también mayor. En otras zonas, como el Atlántico Nordeste, los procesos oceanográficos que sustentan la producción pueden ser diversos.

La enorme variabilidad en las muestras de parámetros biológicos y físicos impide evaluar el riesgo de la concentración de contaminantes y su importancia para reducir las reacciones compensadoras de la producción, que dependen de la densidad. Estudios recientes han demostrado que esta variabilidad puede estar asociada con determinados tipos de mecanismos generadores, e indican medios para interpretarla. Para iniciar programas serios de vigilancia ambiental y biológica es necesario seguir investigando en este sector.

Descubrimientos recientes sobre la variabilidad natural y su interacción con los mecanismos, dependientes de la densidad, que controlan la producción, implican que es necesario un nuevo método, que incluya modelos discontinuos, para prever las respuestas del ecosistema al esfuerzo de pesca y a la contaminación. Pero, sea cual sea su forma exacta, es claro que tanto los modelos de previsión como los sistemas de reglamentación que sobre ellos se apoyen deben tener necesariamente en cuenta los parámetros pesqueros y ambientales, si se quiere que la regulación sea eficaz.

Predictability of Fisheries Production

ALL living creatures are dependent on their physical environment, but this dependence may be expressed in many ways. Some are direct and relatively obvious. Others are so subtle, or take place against a background of such great natural variation, that the relations are difficult to detect without special techniques. It is almost axiomatic that this variation reflects some interaction between environmental change and the capacity of the biological system to respond to stresses such as predation. The important question then becomes, "how great is such interaction?" Significant interaction in an exploited fish population implies that, to be effective, management strategy must take account of both environmental and biological parameters. If there were no significant interactions, regulations could be framed on the basis of biological dynamics alone.

The appreciation of interaction involves a study of the predictability of fisheries production from parameters which index both environmental and biological variables. The research literature contains many examples of the approaches which have been taken. It is not the purpose of this paper to review the research history exhaustively. But there is a discernible pattern in the growth of our understanding of factors controlling population production. This growth pattern has implications for the development of effective management schemes in fisheries, and for establishing research priorities.

For the sake of discussion it will be necessary to agree on a meaning for two words: *adaptation* and *interaction*, which in other contexts may vary in usage. The term *adaptation* will be used to signify a homeostatic or compensatory response of a biological population to disturbance; for example, an increased growth rate following a reduction in biomass, or an increase in the success of spawning with a decreased spawning stock. The biomass reductions in either case may be due to a variety of factors, possibly oceanographic or pollution conditions which dispersed the adults or to fishing which harvested them. In general, the adaptive responses may be classed as density-dependent.

Many important events affecting stock production are not generated by changes in the fishing stocks but by environmental factors, and are generally referred to as density-independent; for example, growth may be affected by temperature, or eggs and larvae may be swept away from feeding grounds. The term *interaction* will be used to refer to situations in which the presence of one factor significantly affects the degree of response to another by magnifying or reducing the relative effectiveness of the density-dependent responses. Examples of situations which will be discussed later are, "does heavy fishing significantly reduce the capacity of the spawning stock to produce large year-classes[2] in favorable environments?" and "do pollutants become distributed and acted on in the environment in such a way that they effectively reduce population production responses to fishing or to other environmental factors?"

It is the hypothesis of this paper that once the temporal and spatial scales of variability have become better defined, and more accurately measured, the interaction of biological and physical phenomena will be recognized as more and more important. The evidence leaves little doubt that it is changes in oceanographic systems which give rise to the primary changes observed in fisheries yields. Within environmental constraints, natural populations exhibit a high capacity for adaptive response. While the mechanisms are not well understood, there is evidence that the capacity to respond is significantly affected by changes in population structure and abundance resulting from heavy selective fishing activity. That is, fishing reduces the response to natural environmental change. In addition, there is evidence that man-induced changes in environment can be large enough to induce gross responses in biological production.

The combined result suggests that in the absence of effective management the more extreme environmental variations, although within the normal pattern which in the past have elicited adaptive response, may in certain situations now have to be considered hazards to continued maintenance of population production levels.

These effects are deduced from interpretation of variations at the low-frequency (of the order of years) end of the spectrum exhibited in fisheries data. There remains a vast class of high-frequency or small-scale variations (hours to months) which are as yet difficult to define or measure with any assurance. The effects of pollution, as well as most of the mechnaisms underlying production changes, appear to be felt directly within this scale of variability. Recent work on the detailed functioning of ecosystems reveals something of the significance of these local events to population control and hence to the development of management strategies. Taken together with the evidence from larger-scale phenomena, results confirm the necessity for joint consideration of biological and environmental parameters in fisheries management.

Development of Biological Models

The principal aim of fisheries research has been to develop management strategies which will maximize the benefits of exploitation. This has required prediction of yield from fish populations with respect to fishing variables which are subject to management, such as season, size of capture, and amount of fishing. Because of the practical importance of fisheries, but because of difficulties with independent sampling, research has been directed to the analysis of commercial statistics with little opportunity for controlled experiments to test hypotheses. Given the complexity of natural events, this objective of optimizing fishing yields has required the greatest possible conceptual simplification, often with the result that the kinds of data collected and the conclusions reached were strongly influenced by prior assumptions about the nature of the system being fished and the state of the fishing technology.

With the emphasis placed on the need for practically useful results, problems of adaptation and interaction in fish populations might almost be considered as nuisance phenomena which cause the actual catch to deviate from expectation. Catch variations have often been treated this way. However, if adaptations and interactions have important influences on long-term yield, careful collection and treatment of data provide the possibility of measuring their effects as deviations in the structure and quantity of yield from the yields predicted by simple population models. The possibilities and the need for this approach have increased with the passage of time.

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[2] Year-class = all fish in a particular population of a species which are born in the same year; eg. 1968 year-class of haddock on the Scotian Shelf.

The first important development in this field of research was based on the work of Hjort on the Norwegian herring fisheries. Hjort showed that major changes in herring catch were associated with the occurrence of occasional exceptionally strong year-classes. Given this major condition, subsequent changes in catch appeared to be more or less orderly, and took place gradually, often over periods of many years. That is, fishery effects appeared to be small and systematic relative to the influence of the natural environment. It was therefore reasonable to conclude, as a first approximation, that environmental effects should be treated more or less independently of effects within the fish-stock itself, possibly even as random variables whose long-term net effect would average to zero.

It was on the basis of such reasoning that Baranov (1918) first proposed a simple population dynamics model in which the effects of fishing would be investigated in terms of the yield per unit year-class strength, or more familiarly yield-per-recruit. That is, it would be assumed initially that major changes in year-class stength, as reflected in their abundance at the time of entry to the fishery, were largely independent of fishing. First-order density effects (those which determine the number of recruits) were to be ignored for the purposes of optimizing practical management, and attention focused on the direct effects of fishing on changes in density and yield, once the year-class was vulnerable to capture. Developments based on this approach were virtually responsible for growth of the whole field of fisheries population dynamics in which the names of Ricker, Beverton, and Holt have played a prominent role.

There are many aspects of this development which are of interest in themselves. What is of most importance here is that fisheries models, constructed on a per-recruit basis, appeared to predict changes in the average age-composition of exploited age-groups in fish stocks. This observation led to methods of estimating mortality rates from relative age-composition and comparisons with changes in the amounts of fishing (Ricker 1958). A knowledge of the growth-rates and weights of animals involved then provided a simple basis for calculating relative yield changes under a variety of fishing conditions. A logical approach to management appeared possible even though the results would be difficult to verify from simple trends in catch.

Ricker (1954) made the first major advance in the theory and practice of fisheries management beyond the developments of Baranov. On the basis of a review of data for a number of exploited and experimental populations, he observed that overall changes in year-class strength were consistent with the theoretical expectations of a relation between the abundance of parent and filial generations of fishes living in a resource-limited environment. If this were generally true, long-term predictions and management strategies based on simple models may be in error in neglecting the first-order density effects. His formulations indicated the manner in which fishing could either enhance or reduce the productive capacity of the exploited natural populations.

Density-dependence within fish stocks has not often been questioned as a concept which may have general applicability. The problem was to find whether it was important enough to require alteration of the simple models on which prediction was based. While analysis in terms of yield-per-recruit provided explanation of some relations among various parameters without invoking density effects, with the advent of computers adaptive responses could be built into the models and their potential influence explored. The results (eg. Paloheimo and Dickie 1965, 1970) suggested that the effects on long-term yields could be large. However, the data showed such unexplained variability that there was always the problem of testing the validity or applicability of any model. Interpretations were questionable, even in cases of natural experiments created by abrupt changes in fishing rates and yield during and after two world wars.

An alternative analytic approach was advocated by Schaefer (1967), who for many years had worked towards the development and application of models which had the concept of density dependence in a limited environment built into them. His models predicted effects of fishing different from those given by the yield-per-recruit models and implied that different types of regulation were necessary to achieve optimum yields. However, the problem of variability remained; the data appeared to exhibit such scatter that they could not be used to indicate which type of basic model was the more appropriate.

Gulland (1955, 1961) in further studies of the variability problem found that statistical data on catch and fishing activity by area and season could be identified and collected in such a way as to permit weighted running means of relative abundance change. He then applied running means of 2- or 3-year periods to the long series of statistical data available for the Icelandic fisheries. The smoothed data permitted him to explore the possible applicability of resource-limited as opposed to yield-per-recruit models to describe them. In the Icelandic data for cod fisheries he found that a resource-limited model appeared to be more satisfactory than the yield-per-recruit model, while the yield-per-recruit model provided a better description for other species. However, on re-examining the data series he further concluded that data deficiencies were such that the available smoothed data were unsuited to providing an objective assessment of the importance of density-dependent effects on long-term natural fish production.

This situation roughly characterizes the nature of some of the problems facing fisheries research and management to the late 1960s. In the next section we review more recent studies which indicate the considerable advances made in this area, particularly when indices of environmental change have been explicitly reintroduced into the analyses.

Production Environment Relations in the Low-Frequency Range of Variations

With the hypothesis developed by early modellers, that methods of optimizing the fishery yield might well be independent of changes in year-class abundance, it is hardly surprising that studies of environmental impact on abundance should have developed almost independently. In fact, the literature shows that the scientific community often became polarized between two camps. One of them espoused the view that fishery exploitation was responsible for all important trends in yield, and called for more comprehensive management. The other claimed evidence that important catch trends were associated with abundance changes related to environmental, or climatic, trends and questioned the efficiency of all or most restrictive fishing regulations.

This state of affairs is well portrayed in the review of Bell and Pruter (1958). They describe in detail a number of papers which develop correlations between yield and environmental indices (mainly temperatures) and discuss weaknesses in the basic data. Three deceptively simple conclusions seem to emerge from their study. The first, which supports the general experience of population dynamics workers, is that year-to-year changes in catch data appeared as much to reflect change in catchability as in true abundance, hence data refinements are likely to lead to significant advances in understanding. The second is that development of correlations between environmental and fishery data is not likely to be profitable until at the very least there is evidence that the data reflect phenomena in an identifiable physical and biological system. The third conclusion is that the correlations must remain suspect unless there is some evidence of the nature of the mechanisms involved. No one expects that it is a simple matter to overcome all the weakness in fisheries data which are implied in these conclusions. There may be no studies which can satisfy all three requirements simultaneously. However, there are a number of excellent recent studies which taken together leave little doubt of the direction of future results.

REFINING THE CATCH DATA

Garrod (1973) treats his fisheries data in a manner which meets many of the criticisms of earlier analyses. He employed the modified virtual population method to calculate mortalities and population sizes of individual year-classes in a number of the major world fisheries. This method uses estimates of catch of a particular year-class at each age throughout its life-history in the fishery, and associates the integrated abundance changes with parallel estimates of relative fishing mortalities. Given the strength of individual year-classes at a particular pre-recruit age, Garrod calculated a replacement index as the ratio of the strength of a given year-class to the estimated average stength of all the year-classes which were parents contributing to the spawning of that year-class. For ease in exposition, Garrod also observed that to maintain abundance any increase in fishing which decreased the spawning stock must be associated with a commensurate increase in the spawning success. He therefore rescaled the parent stock estimates to their equivalent in an unfished stock. This rescaled index he named the relative survival index. If this index changed in proportion to fishing mortality, it would indicate a compensatory response of recruitment to fishing. That is, his analysis was designed to test the hypothesis of significant departure from a curve representing compensatory or density-dependent survival response to changes in the accumulated fishing mortality per year-class.

The results of Garrod's calculations provide what appears to be the strongest general case yet made for density-dependent resource limitation among the pre-recruit phases of fish populations. Despite apparent vicissitudes in natural conditions for survival, there was an increase in the rate of recruitment as fishing increased. Apparently the survival of young was determined by the carrying capacity of the environment rather than by the number of eggs produced. His data also suggested, however, that in certain cases as spawning stock decreased there was an asymptotic change in survival rates, so that at the lowest spawning stocks a maximum egg production and survival may be reached which results in a larval population below the carrying capacity of the environment in a good year.

It may be that clarification of the relations found by Garrod will only emerge once there is a better understanding of the apparently different responses among species and areas. In his analysis, North Sea haddock appeared to be much more heavily exploited than the Arcto-Norwegian cod and yet did not show similar signs of recruitment failure. The California sardine showed it at even lower fishing mortalities. Such differences invoke the question of mechanism, an area which clearly has high priority for future research. For present purposes, what seems of particular importance is Garrod's demonstration that careful treatment of the fisheries data can overcome some of the difficulties in abundance estimation noted by Bell and Pruter. At the same time Garrod's work exposed the possibility of significant interpretations of the higher-frequency variations. He suggested, for example, that residual scatter of the points about the relative survival regression line provides a relative measure of the density-independent variations in survival, or the fitness of the environment for the survival of young fish between the time of spawning and recruitment. This is an acceptable definition to the extent that the virtual population method is capable of eliminating the biases or correlations in the higher-frequency sources of variation treated as sampling errors.

DEFINING THE ENVIRONMENTAL SYSTEM

Garrod's analysis used data for a number of species occurring in well-known historical fisheries. In general, these probably correspond with definable physical oceanographic systems, although this is not explicitly established. Moreover, the analysis does not by itself define the mechanisms through which the population responses operate. In these two areas other investigators supply valuable information.

Sutcliffe (1972) deals with specific physical phenomena in an identifiable oceanographic system, and provides an illustration of the potential of this approach in explaining fisheries changes. His studies began with measurement of experimental parameters relating to the nitrogen budget in a small bay. From it, he concluded that of the order of half the nitrogen supply comes from the upwelling of deeper water into the mixed-layer or euphotic zone. This upwelling appeared to be related to the estuarine vertical mixing generated by freshwater outflow. The possible consequences of such a mechanism were then tested in the Gulf of St. Lawrence (Sutcliffe 1973). The St. Lawrence River is known to undergo marked seasonal and annual fluctuations in discharge and the readily definable area under its immediate influence supports significant fisheries. The results for four different species indicated that more than 60% of the annual variation in fish catch was associated with prior fluctuations in annual river discharge. The average time-lag for the different species suggested that the mechanism of action involved survival at the pelagic larval stages. As periods of higher outflow appeared associated with improved survival, the relation was consistent with the explanation that high nutrients were creating more favorable survival conditions, rather than alternative theories that survival of larvae somehow depends on effects of circulation on their dispersal.

Sutcliffe's hypothesis for the mechanism underlying abundance changes supports the findings of Saville (1959, 1965), who studied the survival and drift of larvae of a number of species in northeast Atlantic oceanographic systems.

Saville and Sutcliffe's results provide evidence for the kind of basic density-dependent mechanism required by Garrod's hypothesis, that is, a long-term compensatory survival of recruits operating in a field of high environmental variation. Their results also substantiate the conclusion of many authors that survival effects determining year-class abundance must operate primarily at early life-history stages. Saville's work further suggests that important nutrient-enriched areas may be found in the vertical mixing generated at boundaries of major oceanic currents, while Sutcliffe's work indicates that they may be identified with regions of strong estuarial action. In the latter case, it is known that the outflow of the Gulf of St. Lawrence has a strong influence on oceanographic conditions along the continental shelf to the south of Cabot Strait and may broadly affect survival and distribution of fish larvae (Serebryakov 1971). Many other major river systems may be expected to have comparable, potentially widespread effects.

Sutcliffe found significant effects on catch of changes in annual outflow over a range of approximately 1:1.5. However if, as he suggested, the mechanism involved larval survival, these annual data must in reality reflect correlated changes in outflow over relatively shorter seasonal periods when the larvae are pelagic. This is confirmed by a more recent study in which the catches are most strongly associated with outflow in particular months (Sutcliffe 1973). It becomes of considerable significance then to note the conclusion of Neu (1970 and personal communication) that regulation of the St. Lawrence River system has altered the within-season outflow patterns of the estuary from an initial ratio of 1:2.9 between seasonal minimum and maximum, to a present 1:1.7. That is, there has been a reduction of the seasonal differences in flow by about 50%. Further flow control of this system as of most major river systems, is contemplated for hydroelectric power development. The within-season flow changes involved are clearly comparable in magnitude to the annual and monthly changes, which from Sutcliff's work appear to affect biological productivity and fisheries yield in the entire system. While the biological effects of seasonal change in river flow patterns and the size of the area within which they may be important cannot now be predicted, production declines in the Azov Sea following regulation of the Don River (Moiseev 1969), or in the Mediterranean affected by the Nile (Aleem 1972), have left little doubt that they can be large. Fisheries management which failed to take account of such effects would have about the same significance as regulation of commercial marine salmon catches when the river in which they spawn is in the process of being dammed.

THE POSSIBILITIES FOR MULTIPLE CORRELATION

While both density-dependent and density-independent effects on larval survival appear to have a major bearing on year-class strength and yield, it would be foolhardy to conclude that biological and environmental variables associated with larval survival alone are sufficient predictors for management purposes. This point has been made by Backiel and LeCren (1967) who point out that survival is likely to be the major density-dependent biological response at larval life-history stages, but growth responses may be of major significance to production among older animals. Cushing and Bridger's (1966) calculations showed how important growth changes may be, whether or not they are actually density-dependent. There is also abundant evidence for growth rate changes in relation both to feeding (Kohler 1964), and temperature (LeCren 1958). We thus have every reason to expect both density-dependent and density-independent influences to operate over the postlarval period. To these must be added the expectation that there will be significant interactions between adult growth and larval survival, because of correlations between growth and fecundity, egg size, and age at maturity (Hempel 1965; Nikolskii 1962). Garrod's evidence for compensatory survival rates in the pre-recruit phases may well have involved a number of such effects for fishes. Density effects among adults are well known for sea mammals, and at least in these cases do not appear sufficient to compensate for reproductive losses under fishing pressure (Chapman 1961; Laws 1962).

Index of survival—Studies such as these often suggest that in natural populations there are so many sources of variation in situations of such complexity that analysis, even with multiple regression techniques, is unlikely to be enlightening. From this viewpoint a study reported by Iles (1973) is an exception of particular importance. He reanalyzed the much discussed California sardine data in a manner which permits more detailed consideration than was possible from Garrod's study. He noted that among fisheries generally, changes in year-classes strength are sometimes reflected in changes in growth rate, especially among the 0-group fish, although this density effect was not always evident from simple correlations, perhaps because of simultaneous large but unmeasured changes in environmental carrying capacity. He therefore calculated a survival index as the ratio of year-class or brood strength to parental abundance.

Iles then studied the rate of change of growth of fish in relation to his density (year-class abundance) and environmental (survival) indices. Their average effects were of about the same order of importance, but the growth response to density changed with the survival index, and became very small under best survival conditions. Considering these observations, Iles deduced that the relative growth might be used to grade estimates of year-class survival in a given year, in relation to the maximum possible survival expected for that year. That is, he could compare estimates of observed recruitment with that expected under standard conditions. Iles' analysis of the California sardine shows parallels with that of Garrod, and it is unfortunate that at the present time the published data do not permit detailed comparison of their indices of survival. If subsequent study reveals that the two sets of survival or replacement indices are in substantial agreement, Iles' results provide strong support for the hypothesis that actual replacement rates of sardines in the later years of the fishery were lower than the environment could have permitted. That is, the spawning stock was severely reduced by a combination of naturally poor brood years with an intensification of the fishery. The combination prevented recovery in later good brood years. On this basis, development of the anchovy population on the sardine grounds must be seen as a consequence, rather than a cause, of the sardine fishery failure.

Iles carried his analysis an important step further and compared indices of (environment) survival among various fisheries and areas (Pacific salmon and herring, Alberta whitefish). While it is important to remember that the treatment of the catch data is not necessarily comparable to the analyses of Garrod, the results are striking. They show strongly associated variations in relative survival for different species within oceanographic systems. They also indicate significant associations over wider geographic areas, which suggest that mechanisms giving rise to year-class fluctuations may ultimately be measurable in terms of changes in meteorological systems. We are thus brought back full circle to the subject matter reviewed by Bell and Pruter, but with the conclusion that improvements in the data appear to verify the reality of the relations which they questioned.

Capacity for population responses — As frequently seems to be the case in science, the return to the original subject matter is not so much a circle as some form of spiral. From the more recent analysis we may now conclude that within the broad constraints of environmental carrying capacity, fish populations show a remarkable capacity for density-dependent response. This response clearly involves reproduction, apparently in important association with the feeding opportunities during the youngest life-history stages. It further appears that severe predator pressure, such as is now experienced by some long-lived adult fish stocks, measurably reduces the effectiveness of the biological compensating mechanisms, and increases the probability that fisheries on them will suffer economic collapse. In at least the Californian sardine situation the population balance appears to have been sufficiently upset that the structure of the producing community has changed to some new kind of equilibrium.

These conclusions do not represent anything new in concept in ecological theory or experiment. What is new is the demonstration that even with existing high levels of natural variability, interactions can apparently be induced in large wild population systems by predation pressures generated by present economically and technologically supportable rates of fishing. To this conclusion must be added the likelihood that current man-induced environmental alterations in estuarial regions are within the order of size which significantly affects the level of production in biological systems.

As was pointed out earlier, we are still not in a position to understand the larger question of why the limits of adaptive response by fish populations should be different among species or between areas. Riley (1972) reviews information on productive efficiency and community structure in three oceanographically different ecosystems and indicates that while differences in overall primary production seem quite clearly related to nutrient supply conditions, it is not easy to understand differences in the subsequent pathways of energy flow. We are far from being able to anticipate the long-term effects of heavy fishing. On balance, it is likely that as our knowledge grows we will find that the adaptive responses shown by Garrod for single species apply *a fortiori* to the complex of fish species comprising most communities. That is, we may find it possible or even necessary to deal in management with the multi-species population, as suggested by Parker (1962).

Implications for fisheries science — The foregoing has at least two important implications for future fisheries science. In the first place we may recognize with earlier workers in population dynamics that environmental variables are random or stochastic. But when they operate on a biological system their effects do not average to zero, even though their expectation values may be zero. Once an extensive event has occurred, its influence is felt in the system for years to come. The effect on future stocks of a severe winter this year will not be removed by an exceptionally mild winter next year. Therefore, even without significant changes in environmental patterns, any reduced adaptability from fishing or other causes implies that variations, which in the past elicited adaptive response, may today result in catastrophic change. The management system must necessarily consider environmental as well as fishery variables.

The second consequence is that under present conditions the concept of continuous models of fishery ecosystems may be inapplicable at the species level. In fact, the problem of determining at what level of population or community of organisms continuous models may be used, and the relation of their population systems to their component species, has changed from an intellectually interesting exercise to a question of practical importance requiring early understanding. The importance of these interactions is underlined by the California sardine history.

The Pollution Problem — Interpretation of High-Frequency Variability

From the foregoing we infer that the general properties of single-species fish populations are reasonably well established as a basis for predicting shorter term trends, of 3–5 years. However, such predictions rely undesirably heavily on running averages of data, necessitating an assumption that the higher-frequency variabilities are effectively cancelling out. To increase accuracy and reliability of prediction the immediate task of the resource research program must therefore be to study the short-term variability in sample data, with two principal objectives in view: to ensure that testable predictions can indeed be made; and to ensure that predictions for a system can be based on fewer data than were required for its initial description.

In these respects the approach of research programs in resource managment becomes very like that required for pollution. Pollution research has, of course, requirements of study which are more or less peculiar to it: it must provide information about the effects of a great variety of chemicals on feeding, growth, reproduction, activity, and survival of various life-history stages of many aquatic organisms — a large program indeed. But while pollutants are taken up by individuals, it is their collective effects on natural productivity and exploitable yield that are the chief concern of fisheries management. That is, we have to measure the effects of pollutants on the same adaptive responses that have been the subject of resource research. This requires an understanding of pollutant distribution, uptake, and effects in relation to rather precisely defined details of the ecological production mechanisms.

Evidently, assessing pollution effects in nature, and monitoring to detect significant changes in levels of hazard, requires that we face the problem of describing and interpreting the high-frequency variability of samples. While this is an area in which we are still weak, our experience has grown rapidly in the past two to three years. Recent scientific literature indicates some of the problems involved in carrying out pollution sampling studies, identifies methods by which they may be resolved, and gives some indications of the more promising lines of research.

UPTAKE OF POLLUTANTS

The problem of uptake of pollutants has been considered in a recent review by Kerr and Vass (1973), with particular reference to the apparently ubiquitous DDT and PCB compounds. They conclude that uptake in aquatic systems is overwhelmingly associated with diffusion through respiratory surfaces and is therefore a function of metabolic rate and available concentrations. On this basis it would be expected that concentration per unit volume would be generally higher among the smaller organisms than the larger, a fact which is generally confirmed by sampling (Ware personal communication). Food-chain transfer appears to be secondary in importance in aquatic systems, a fact which may make them different from terrestrial systems and have important implications for differences in regulatory measures. Given this information as a basis for preliminary pollution models, it still appears that where aquatic animals are large and relatively long lived, the larger may show increasing pollution concentrations, especially where they feed on small particles as do whales and fast-growing large pelagic fishes. In these cases, metabolic conversion and elimination rates of pollutants play an important role in explaining observed concentrations. There is relatively little information about these physiological properties of the larger animals and fishes.

If this basic uptake model is upheld by further work, it suggests that the study of local distribution of pollutants in relation to the life-history stages of fish, particularly of the pelagic larval and 0-group stages, is an area for high priority research. Pollutants seem most likely to be concentrated in the surface layers or in coastal embayments and estuarial mixing zones, those very areas where year-class success is most likely to be determined.

PRODUCTION PROCESSES IN BAYS

Platt and Conover (1971) studied in detail the processes of production and exchange of waters in and out of a small coastal bay. They sampled hourly, over a period of a day, for physical, phytoplankton, and zooplankton parameters, supplementing the field observations with laboratory experiments to determine certain physiological rates. Their results indicated that about 60% of the daily chlorophyll production was exported from the bay, the remainder being almost all taken up by zooplankton grazing. Production of zooplankton could not be accurately measured, but the amount exported was measured in wet-weight terms and found to be equivalent to approximately half the export of the phytoplankton.

The most important aspect of their study was the examination of mechanisms of transport of organisms in relation to the physical water transport. The hourly data showed a strong negative correlation of the concentration of organisms with rate of transport (obtained using continuously recording current meters), with the result that only 35% of the daily export of phytoplankton and less than 1% of the zooplankton exchange were associated with the mean flow. That is, 65% of the phytoplankton and almost all zooplankton export from the bay were associated with the fluctuations (hourly) in the flow, apparently associated with tidal influences, although some 2.5 hr out of phase with it.

These observations suggest three conclusions of significance to pollution studies in relation to fisheries production. First, a high proportion of the daily biological production of coastal inlets is exported from them, and the amount exported is much higher than the measured net mean water exchange. Evidently, coastal inlets and estuaries are much more important in supporting production systems of coastal waters than has been estimated in the past by multiplying the net physical exchange by the average primary production. As coastal inlets are also especially liable to pollution effects, this finding alone suggests that coastal inlets require much more priority in fisheries research programs than has generally been given them. Of second importance is the finding that a high proportion of the production exported from coastal embayments may be at a relatively high trophic level, and that the amount exported at various trophic levels or particle sizes may be very different. A relatively high trophic level of the export would make coastal inlet production that much more important as a source of nourishment for larval and juvenile fishes, which are commonly found to congregate in the near-shore areas at some stage in their life history. As pollutants are generally associated with particulate material in the water, but their concentrations vary with particle sizes, we must conclude that many detailed experiments and observations are necessary to permit generalizations about the dissipation or flushing of pollutants from inshore areas, or the significance of their contributions to the coastal waters. Finally, Platt and Conover's work shows that mean water exchange from coastal inlets is not by itself a reliable estimate of biological exchange. The more significant parameters are associated with phenomena at the high frequency end of the scale of variability. Such observations suggest that requirements for pollution monitoring programs are far from simple and, at least for the important coastal and pelagic zones, would have to be carefully designed around a knowledge of existing conditions if the results are to bear any relation to reality.

VARIATIONS IN PHYTOPLANKTON AND ZOOPLANKTON

Platt (1972) studied the nature of high frequency or local scale variability in phytoplankton in the mixed layer. Chorophyll concentrations were continuously measured at a point station in the Gulf of St. Lawrence at 8m, using a fluorometric technique. The station was occupied during midsummer outside the main spring bloom period. He found that fluctuations in concentration of chlorophyll were satisfactorily described by a minus 5/3 power relation over space scales of from 10 to 1000 m, or time scales of from 1 to 100 min. This suggests that not only do the high frequency fluctuations present in oceanographic sampling exhibit a definite pattern, but that for phytoplankton this pattern may be strongly influenced by small-scale events in the physical medium. The possible relation with turbulent flow suggests that analogous generating mechanisms may be of considerable significance to the design of appropriate predictive models of dispersion and uptake of pollution in biological systems.

Steele (1973) examined the nature of fine-scale zooplankton distribution in nature, in relation to zooplankton dynamics. Using estimates of growth, mortality, and grazing rates from laboratory experiments, he calculated time series of phytoplankton-zooplankton biomasses, which under certain conditions show considerable fluctuations. From the models he was able to estimate their joint probability distribution for different population abundance states. This he compared with the frequency distribution of biomass samples taken over a relatively short time in a dispersed zooplankton patch. The fit of the natural variations was satisfactorily close to the calculated distribution, although it was somewhat dependent on estimates of rate of sinking of zooplankton from the population, a phenomenon which seemed not to be satisfactorily identified and measured in nature. This result suggests that fine-scale distributions of zooplankton are far from random. In the case of zooplankton, in contrast to phytoplankton, fluctuations appear rather more dependent on the population dynamics than on the medium, but the important result is that distribution can be understood in relation to environmental and biological generating mechanisms.

The results of Steele's work support those of Platt and others which indicate that assessment of the influence of various factors, such as pollutants, on ecological production processes is not yet a job for amateurs. The results clearly indicate, however, that such assessment can be done, provided we are prepared to put the effort into studies of the kinds of variations that have frustrated fisheries resource research in the past. That is, it should be possible to make the kinds of generalization which will permit pollution assessment without invoking the astronomical expense of detailed study of each individual potential pollution site.

Conclusions

In studies of fisheries resource management problems, the limited amounts of physical research resources have frustrated many of our attempts to understand the basis for observed catch changes, sometimes for no other reason than we have been too busy trying to cope with measurement of the symptoms as they showed up again and again in important fisheries. In retrospect, this situation may not have been so very bad. For one thing, the longer series of annual data now available have made it possible to measure production changes in relation to a much wider range of fishing mortalities, and are only now on the point of exhibiting significant interactions. Perhaps we could not have anticipated these effects much sooner in any case. In addition, it appears that fishing effects alone have not led to irreversible population changes. The Antarctic whale fishery, perhaps the most seriously affected, disappeared many years ago. But this situation had been detected by the scientific community; the failure was a result of slow international administration, accompanied by a poorly or insufficiently informed public. The populations may recover in time. The California sardine fishery collapsed, but the geological record indicates that the sardine has been replaced by the anchovy at various periods in the past, so that the effect of heavy fishing may only have been to increase the probability of a natural adaptation of the productive community. And now the research results have indicated that there appear to be rather clear-cut short-term alternatives for the Arcto-Norwegian cod. Thus, while we are still unable to foresee the longer term consequences of ecosystem change of the kind which lead to fishery collapse, the possibilities for short-term diagnosis of symptoms is encouraging and justifies continued efforts toward the understanding of fishery conditions.

Unfortunately, pollution problems are not quite the same. Effects of pollutants arise from disposed chemicals which have accumulated or are accumulating in the environment. We cannot afford to wait until the symptoms of their action show up in significant production changes in order to test the validity of scientific models describing their effects. By the time we are able to test the theories by the results or symptoms, the time scale of recovery is likely to be so long as to make it a practical impossibility. It is necessary to anticipate pollution effects and take preventive action. This necessarily involves a knowledge of mechanisms responsible for production control and pollution effects in nature. That is, it requires specific and detailed studies of the sort which have been slow to develop in traditional fisheries research.

It must also be emphasized that effects from pollution appear likely to be most profound in those parts of our world where pollutants are most likely to become concentrated — the coastal fringe and the mixed water layer over the continental shelves. That is, they occur in those areas where our studies indicate that control of production of commercial species takes place. Given the evidence that interaction of fishing and natural environment change is significant, it is inconceivable that pollution effects will not be found to magnify the interaction.

We can only conclude that fishery resource management has special reason to promote our understanding and prediction of pollution effects, and to insist on their control. In its simplest terms, it is clear that resource management of our continental shelf fisheries cannot effectively take place independently of the insurance against deterioration of the quality of the environment. We have every reason to believe that the resource science community is relatively well prepared to carry out the work. However, it is virtually certain that this will require a more intensive, detailed and sophisticated study of natural ecosystems than has been our custom. Solving this problem is very much the responsibility of government administrators, politicians, and the public.

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Report on the Closing Session

Fisheries and the Environment

1. Attention was called to the fact that conditions and activities on land may have a strong impact on marine fisheries, by way of their effect on estuaries, bays, bordering areas, and straits. These coastal areas determine the effectiveness of fish reproduction and hence the yield of major stocks. Fish are affected not only by factors such as pollution, but stabilization of river flows by hydroelectric developments can also influence them profoundly.

2. In any event coastal countries, particularly if they harvest the sea, have a responsibility for maintaining its health. For example, countries bordering the Baltic Sea are taking measures to control and reduce pollution there.

3. Where undesirable contaminants (whether artificial or natural) are present in fish this can affect fishing strategy and management—for example the best size of fish to maintain in a stock.

Fisheries and Fisheries Management

4. The economic welfare of the fishing industry should always be borne in mind when measures for resource management are considered. Fishing is by its nature a high-risk venture, so that artificial risks should be minimized. Scientists should therefore be as accurate as possible in their predictions of available stocks and permissible yields. Administrators should avoid changing their policies in ways that could seriously damage the viability of a particular fishery.

5. To take advantage of the experience of the developed countries for the benefit of those undergoing development, it was suggested that FAO play a greater role in placing developing countries in contact with experts, including industrialists from the more developed areas. This could be of assistance in joint venture arrangements, as well as in broader international developments. Joint ventures appear to be one of the best means of capital and technical assistance, though by their nature they call for an early profit. To create the economic climate within which joint ventures can operate it may be necessary initially to provide other forms of assistance.

6. It has been widely recognized that countries receiving assistance have the right to indicate which way development should be carried out. However, it should be equally recognized that donor countries should have some influence in assessing the practicability of the projects undertaken.

Population and Employment

7. A major factor in the economic and social position of many developing countries is rapid population growth. This creates problems, particularly as regards the provision of useful employment. In many countries agriculture and fisheries must support large numbers of people for the indefinite future. Where the fishery resource and the employment situation permit, it is frequently desirable to upgrade the artisanal fishery. In many cases, however, the situation may require that this fishery be shielded from technical improvements which would significantly reduce employment.

8. New artisanal fisheries may be developed in some areas, e.g. in inland waters. They should be as labor intensive as possible, while still being in a position to sell at competitive prices.

9. Training and education were stressed, as well as the related problem of better communication with fishermen, who usually know and care little about the results of research activities. Serious attention should be given to bridging this gap.

Proposed Increase in Capability for Research, Training, and Transfer of Technology

10. It was suggested that greater provision must be made for centralized analysis of research results, improved training and the rapid mobilization and transfer of technology among nations. A number of participants indicated that the Director-General of FAO should be requested to explore ways and means of strengthening the activities and capability of the Organization in these sectors. The possibility of setting up a specialized unit within the framework of FAO's Department of Fisheries was mentioned, but it was the general view that this was a matter that ought to be considered by intergovernmental bodies such as the Committee on Fisheries. The Conference was informed that if it were decided to create such a unit, Italy would be prepared to provide suitable facilities in Rome.

11. The Conference emphasized that in view of the ever greater demands on the Department of Fisheries of FAO, a major increase in the financial resources available to it would be necessary in any event.

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Chairman's Summary of the Highlights of the Conference[1]

A. W. H. NEEDLER

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I want to make it clear that I am not speaking for the Conference at this stage. Tomorrow we are going to discuss what this Conference will report. Now, I am simply giving a personal summary as Chairman, to give us some perspective and help us in our deliberations. The Secretariat is using this afternoon to see that the accounts of the Technical Sessions, which will appear in our report, will be in your hands so that you will be prepared to discuss the report tomorrow.

This has been a most interesting Conference. I have never attended a conference where so many active participants from all over the world have discussed the subject of Fisheries Management and Development. From that point of view this conference is already a success. One of the problems that we discussed rather thoroughly was the problem of communication between administrators and scientists, communication between national and international organizations — the problem of getting the ideas and information from the scientists and economists to the people who use the information. And this conference has already been valuable in that respect. It is not our duty to take any executive action; but we have been exchanging points of view to an extent that I have never experienced before, although in some of the meetings of the FAO Committee on Fisheries this has been approached.

I would like to give you some of my impressions of what is new or important that has come out of our discussions so far. I think this is the first time that it has been unanimously recognized that the fishery resource is not unlimited, and that indeed it might level off, if we continue to use our present methods and exploit the kinds or sizes of organisms that we are now using, at about 50% above the present level of production. There is no magic about the figure 100 million tons, but this is the general order of magnitude. It has also been said that the demand is almost certain to continue to rise as population increases.

Fish and shellfish provide protein food of high quality, which is valuable as a supplement to diets. It provides amino-acids and elements that are not too common in diets, especially of less privileged people. Less privileged is perhaps the wrong word; I sometimes think that people are privileged if they are living in a society not so committed to the sort of economic rat-race that ours is.

If the demand continues to rise and the resource levels off, one can expect that the difficulty in selling fish will become less and less: there has been a tendency already for fish prices to rise faster than the general level of commodity prices. What this means is that there will be more pressure on the resource. The pressure is already intense but will become more so, and this underlines the urgent need for adequate management to sustain the yield. The majority opinion here seems to be that the need for management to sustain the yield is already the rule rather than the exception. It also underlines the need to avoid material or economic waste. We need to get the best out of the resource, which 15 or 20 years ago we thought was so far above production that we didn't need to worry. And we need to seek means of increasing the supply through aquaculture, important in tropical latitudes especially, and probably of seeking larger supplies in certain instances by using organisms at a lower trophic level. We all remember the indication of the size of the resource of krill, for example.

Now I felt a bit discouraged in the first half-day because it seemed to me that when we were considering the scientific basis for management the scientists were saying: "We don't really know how to manage." Next day they came back and said: "We know how to manage, but nobody is doing anything about it."

As this Conference has proceeded we have realized that a great deal is being done, but that there is a basic need for much more application of science, and I say "science" advisedly and not "research." I mean the application of scientific techniques that are already known, and the application of economics. Both of these require that there be adequate data. And this is one of the matters that the conference has stressed. Indeed, many participants have mentioned the responsibility of any who use the fishery resource to provide adequate data for good management — good management not only biologically, but also economically.

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[1] Prepared for the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

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This idea should be coupled with another point, that in the management of fisheries, for conservation purposes or development, there is a need for a broad, integrated approach of science and economics. One of the needs that was stressed is the need for research; the more urgent need is for enough data to let us apply the science we have, but certainly there is also need for research to provide the basis for more adequate, broad, and sophisticated management of the ocean, to provide the basis for development of aquaculture and so forth.

So we have stressed a situation in which we have a limited resource, an increasing demand, and a need for better management to preserve the resource, better steps to avoid waste, and more adequate steps to increase the supply. All of which must be based on scientific effort, some of it application of existing principles and some of it imaginative or innovative research.

The next point that seemed to be stressed — certainly there were no dissentient voices — was the need to remember that the fishing industry, especially in the developing countries but also in the developed countries, is an integral part of the whole economy of the country, and planning for management and development must be done with that in mind. Management measures and measures for development must be formulated on the basis of the general social and economic needs of the countries concerned.

The objectives of fisheries management and development vary greatly from country to country and from region to region. In some countries, it is the provision of food for their populations that has the highest priority; in others a greater need is for employment and for money for foreign exchange, and so forth. And any attempts to aid development, or encourage or aid countries in management of fisheries, must be planned as an integral part of the countries' activities, and it follows from that that the country receiving the aid must have the major voice in the form which the aid takes. This goes without saying, simply as a matter of authority, but it should be recognized in all cases by donor organizations or donor countries. Another point that was stressed strongly was the human element, and one of the speakers said that in all of this endeavor what we are really interested in is people. We must help people in the way in which they need to be helped. And we gave a great deal of special attention to problems of developing countries.

There seem to be two broad aspects concerned for the fishing population. One is the support of the so-called artisanal fisheries, the small-boat fisheries — canoes and small motor boats. The development of fisheries which support these populations has a high priority. Regardless of whether there is also development of an efficient modern fishery using larger vessels and more sophisticated equipment, there is a need to look at the problems of the artisanal fisheries. The point was made that these are not necessarily in conflict, because development of a modern fishery gives better opportunity for marketing and distribution of the product of the small fisherman. It is clear that in the minds of most participants the welfare of people is the most compelling objective, and a great deal of attention was given to the complicated problems of helping the artisanal fisherman.

Another point that was made quite clearly was that aid to the developing countries must not only be adapted to the needs of those countries, which must therefore have a major part in determining its direction, but aid must also have an adequate follow-through, and this involves recognition of the time scale on which aid can be made effective. The conference at various times discussed ways and means for providing all sorts of aid. FAO was mentioned naturally as being an organization dedicated to aid the developing countries. FAO has as one of its primary objectives, explicitly stated right at the start, the welfare of rural populations.

There was also discussion of bilateral arrangements of two sorts. Bilateral arrangements between research institutes were mentioned as being an effective way of transferring technology, and this should commend itself to all countries interested in giving aid to the developing countries. Under such schemes the research workers in the developing country are in close contact with those from more developed countries and can learn during their work.

Another way of transferring technology, mentioned many times as having demonstrated value and capable of great expansion, is the use of joint ventures. These might often be between industry in one country and government in another, but joint ventures of many sorts.

It would be safe to say that the transfer of technology is recognized as perhaps the key problem in giving aid to the developing world. Financial assistance of one sort or another may appear to be more important, but to be lasting in its effects transfer of technology at all levels is very important.

I was interested in the extent to which national problems were discussed at this conference. I would think that the discussion was most often in terms of national problems and national needs and how these could be met. But it was also clear that a strong regional approach was in evidence, as well as the recognition of world-wide influences and problems.

To return to management of the resource before going on to look at some of the regional differences — it seemed to be recognized that broad management of a resource, recognizing both scientific and economic factors, should be undertaken early in the development of each fishery. This is partly to forestall the sudden impact on the stocks of a fishery that often goes too far, and partly to forestall the overcapitalization that is often a feature of the development of new fisheries.

I'll touch briefly on impressions from our discussion of certain regions. Unfortunately, we did not have time to cover the whole world, but we did give some special consideration to certain regions as examples. One was the southeast Pacific. It sounded to me like a success story of the development of a large modern reduction fishery, especially in Peru, where the anchoveta fishery is most strongly developed, but also in the two neighboring countries of Ecuador and Chile. This seemed to be a success story in development, a success story in aid which was done in an appropriate way, and a success story in research, in that research to manage this fishery and prevent overexploitation has been instituted in an effective way a relatively few years after this fishery was started. However, management did not come in time to prevent overcapitalization and management problems. In this district there were also in the background the broad problems of inshore fishing populations, and it was obvious that there were many possibilities for development in that field.

In the Eastern Central Atlantic the situation was more complex, but again there has been much development. An urgent need for management has been recognized, but management has not progressed as far as the countries in that region recognize it should. In spite of great complexity, there seemed to be a strong regional approach and a strong feeling of present cooperation and more potential cooperation internationally within the region. Again there are the two aspects of large-scale development and of the artisanal fisheries. There were some examples of aid: I was much encouraged to hear of Canadian aid being carried out in an appropriate way. There were many other cases, and perhaps I should not mention my own country.

We were not able to give the Indian Ocean, which is the most complex region, as much time as it deserved. Those engaged in the discussion of the Indian Ocean problems really deserve an apology, in that they were only able to get about halfway through their discussion. However, there were some extremely interesting examples pointed out and, in one case, of the early need for management, the economic benefits of reducing fishing effort. We certainly hope that bodies like the Indian Ocean Fishery Commission, FAO, and the national agencies can make good progress.

In the North Pacific, we have had great development of fisheries since the second world war; as a whole, exploitation of the resource is approaching its maximum. There have been in the north Pacific good examples of the rapid impact that large mobile fleets can have in developing fisheries, and in developing them to, or perhaps past, their maximum exploitation. We have a great complex of international and bilateral agreements directed towards particular problems. There certainly is not an adequate international structure to give comprehensive protection to the stocks. Surely we are capable of some improvement.

In the north Atlantic, we have some of the oldest fisheries and the earliest technical development of fisheries. We have the largest pool of technological and scientific expertise. Many people think progress has been disappointing, and there is a lesson to be learned from the north Atlantic experience. It is that the conservation bodies were hindered by the provisions of their own conventions. When regional bodies are set up with the objective of managing the fisheries resource, the original conventions should not be restrictive of the methods that can be used, or at least as little restrictive as possible. In the commissions on both sides of the Atlantic there have been delays for several years, due to the necessity of changing a convention (that seemed adequate at the time it was negotiated) to make it capable of meeting modern conditions. The North West Atlantic Commission is an example of that. It first spelled out the measures that could be used, then it took some time to remove those restrictions. When the necessary amendments to the convention came into force, action was taken quickly; catch quotas were established and national allocations of quotas were established which permit each country to rationalize its operation from the economic point of view. This was done for a majority of the important stocks within 6 months of obtaining the authority. I throw this out to the scientists who have suffered a good bit of frustration. But of course an international convention can be changed only when every country agrees and ratifies, and that takes time.

A discussion yesterday on distant-water fisheries served to show the different points of view of those with large mobile fleets and of those with inshore fisheries and fleets that are not as mobile as the large mothership or factory trawler operations. However, it was clear that some resources can be harvested only by the large mobile operations. This will be true, for example, of the krill in the Antarctic, and was substantially true of the great development of the Bering Sea fisheries. However, there is a need to see that regulations control the impact of these large mobile fleets on the inshore fishing industry of coastal states. This is close to the boundary of our terms of reference, but there is a problem in management, which is being faced by some regional bodies and which may well be greatly affected by action in other forums in the next few years.

To sum up, we have recognized the need for management, the need for a better scientific basis for management to sustain the yield, the need for integrating science with economics to lead to rational economic management, and the need for more effective regional resource management in some cases. We have emphasized the challenges for the future, of improving the resource by aquaculture, or by managing the ocean. Perhaps, if we can go to the moon we can also change the oceanic circulation, sometime. The fact that there is a limit to the world production with present techniques of fishing and the sorts of animals we now catch, does not mean that there is no future for the young men. There is much for the next generation to do in this field — the management and development of fisheries.

We have sometimes approached close to the border of our terms of reference. I thank all who would have liked more discussion of jurisdictional matters at certain times, and who have exhibited commendable restraint. However, this conference has demonstrated the value of exchange of ideas on technical matters and the increasing need for a world forum for such exchanges, as well as continuing need for internationally organized or bilateral aid for developing countries. We have provided a background that will be useful in the consideration of jurisdictional matters in another forum.

This conference has been valuable already. More than one participant has said that this conference would be valuable even if it didn't produce a report. We do have some commitment, however, to have a report and that is our next job. This is not the time to discuss the sort of report it should be, or its content; we have tomorrow to do this. In the meantime, summaries of the technical discussions which may form part of this report will be distributed, and also some suggestions of recommendations that might emerge from this conference.

Thank you very much.

Conference Recommendations[1]

Planning

The Conference recommended an integrated approach to fisheries development planning, and emphasized that it was essential to take account not only of scientific data and information but also relevant social and economic factors.

Fisheries Data

The Conference stressed that rational fishery management and development requires adequate and timely statistics and other data relating to fisheries. Noting that good management is in the interest of all countries participating in a given fishery, it recommended that governments concerned exercise their responsibility to ensure that national and international management institutions are provided with adequate data not only on the resources and the catch but also on the fishing effort. It further urged that governments and international fishery bodies take steps to improve fishery data systems, to adopt common standards and to implement the present recommendation. It was noted that the responsibility to provide suitable data implied the corresponding right to take part in any assessment of these data for management purposes.

Need for Early Management Action

The Conference noted that management to protect resources and maintain the yield is already overdue in many instances, and should indeed always be started early in the development of a fishery. It was also noted that techniques are already available for immediate application, although some improvement may be expected. The Conference requested the Director-General of FAO to call the attention of Governments to this urgent need, and where appropriate to take steps to assist in the implementation of the necessary measures.

Science and Development

For the successful management of traditional and new fisheries good scientific advice is essential. This advice should be based on stock assessments and models of the dynamics of fish populations, but in addition biological and oceanographic research are required to solve specific questions related to the improvement of assessment and models, for predictive purposes, the development of aquaculture and for environmental manipulation and protection.

Planning and preinvestment studies and those aimed at reducing risks in fisheries activities require more accurate and regularly up-dated assessments of fishery resources and better prediction of their behaviour under environmental conditions and man-made stresses. More effective scientific and technological know-how is also needed in support of both artisanal and industrialized fisheries, in all their phases, from catching or farming to marketing.

The Conference, therefore, called the attention of Governments, UN agencies and other international and national bodies to the need to adopt measures to provide appropriate funding and support for research as an important element of fisheries development and management.

Long-Distance Fleets

The Conference expressed concern over the growth of large long-distance fleets in the face of the rapidly approaching limits to full exploitation and recommended that all efforts be made to take effective measures for the protection of the stocks where long-distance fleets might be in competition with coastal-based vessels.

The Conference recognized that in some instances long-distance fishing limits the opportunities of developing countries near the fishing grounds to undertake the exploitation of the resources. The Conference therefore considered that in these cases the capabilities of the developing countries should be strengthened by, inter alia, appropriate technical and economic assistance.

Enlistment of Industrial Skills in Development of Fisheries in Developing Countries

The Conference recognized that international cooperation was essential to accelerate the growth of the fishery industry and to economic growth in developing countries. Noting that present programmes of assistance by international agencies and donor countries are not bringing about development at the desired pace, the Conference recommended that the administrators of aid programs, in consultation with FAO, should explore means of drawing on the material resources, skills and experience of the established

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[1] Prepared by the "Technical Conference on Fishery Management and Development," of the Food and Agriculture Organization of the United Nations, held at Vancouver, B.C., Canada, February 13–23, 1973.

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fishery industries in the developed countries for fuller involvement in developing countries. It further noted that joint ventures, usually involving an enterprise in an economically developed country and a Government or other enterprise in a developing country, were a suitable mechanism to effect the transfer of essential components of viable fishery enterprises, including capital, technology and managerial skills. The Conference recommended in this connection that FAO should consult with Governments regarding the further role it could play in enhancing the participation of developing countries in fishing industries, including studies on how joint ventures could be made more effective.

Promotion of Research and Training in Fishery Resource Management and Development

The Conference stressed the urgent need to solve in a rapid and efficient manner the increasingly complex and multidisciplinary problems posed by the rational management and development of world fisheries. These problems are scientific, technical and environmental as well as social and economic in nature. The Conference noted with appreciation the useful work already carried out by FAO and its regional fishery bodies to assist governments in coping with these problems. It realized, however, that this work needed to be further developed, especially as regards the promotion of research and training, bearing in mind the specific problems in tropical areas and the special interests of developing countries. The Conference therefore invited the Director-General of FAO to explore, in consultation with governments, ways and means of strengthening and supplementing the relevant activities of the Organization. The Conference noted with great interest the role of bilateral partnership arrangements between research and university institutes of developing and developed countries in the promotion of research and training in fishery management and development, and emphasized therefore that such activity should be extended because of its great efficiency.

Multiple Uses of Aquatic Resources

The Conference expressed concern that other uses of the aquatic environment impinge on fisheries, and that this is particularly acute in respect to inland fisheries, coastal fisheries and aquaculture. The Conference therefore felt that Governments and international organisations should pay attention to this, and wherever possible, should take effective measures to control harmful effects, especially pollution so that the survival and value of the fisheries is protected. This will require integrated multidisciplinary research as a basis for comprehensive action.

Waste

The Conference noted that a substantial extra tonnage of fishery products might be made available without additional pressure on the stocks by better utilization of incidental by-catches and discarded or neglected fish, and preventing losses caused by inefficient handling and distribution. The Conference recommended that more efforts be made to achieve these objectives.

Aquaculture Research and World Conference

In view of the growing demand for fish, the Conference considered that the development of aquaculture techniques should have high priority. Among the measures to be taken should be the strengthening of coordinated regional research activities. The Conference also invited the Director-General of FAO to organize the planned World Technical Conference on Aquaculture as soon as possible.

Training

The Conference noted that for developing nations to participate fully in the worldwide program of fishery management and development they must have trained personnel. The Conference therefore recommended that every effort be made to enhance the training of such personnel.

INDEX OF PROCEEDINGS

Subject-Author Index to this Issue

This issue is devoted to the proceedings of a conference dealing with many aspects of development and management of widely varied fisheries, and it was not considered practicable to index in detail the voluminous and sometimes repetitious information and data presented by the participants. Consequently, the subject headings selected represent mainly the principal topics emphasized at the conference. Of the many land areas, bodies of water, countries, fishery methods, products, and uses dealt with, those specifically mentioned in titles or section headings are indexed, as are some other subjects of importance.

Page references given are initial page numbers of the presentations.

The separate index of scientific and vernacular names that follows the Subject–Author index includes substantially all aquatic organisms mentioned in this issue. It should assist in locating information on countries, areas, bodies of water, etc. not indexed, but to which the fisheries for these organisms may apply.

Certain geographical areas (particularly oceans) have major subdivisions designated by N (north), S (south), E (east), W (west), NW (northwest), etc., also Atl. (Atlantic), Pac. (Pacific).

Certain international commissions are commonly referred to as:

IATTC–(Inter-American Tropical Tuna Commission); ICCAT–(International Commission for the Conservation of Atlantic Tunas); ICES–(International Council for the Exploration of the Sea); ICNAF–(International Commission for the Northwest Atlantic Fisheries); IOC–(Intergovernmental Oceanographic Commission); IOFC–(Indian Ocean Fishery Commission); IPFC–(Indo-Pacific Fisheries Council); IPHC–(International Pacific Halibut Commission); IWC–(International Whaling Commission).

In the index references, "re" is frequently used to imply "in relation to," "in connection with," and similar meanings; "vs" to imply such meanings as "in contrast to," "as opposed to."

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2463 (Ghana's experience in distant-water fisheries)

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2486 (to fisheries administrators)

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Ahn, Myong Nam
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Alverson, D. L.
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2109 (world catch of, 1964–1970)

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2226 (stock assessment & fisheries management; biology; predation by birds)
2236 (example of establishment of a fish food industry in Peru)
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2341 (development prospects for brackish-water fish & shrimp in India)
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2226 (of Peruvian anchovy (*Engraulis ringens*) stock re fishery management)
2393 (future, of Pac. halibut fishery)
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2264 (management & development of fisheries)
2276 (meeting economic & social objectives in fisheries of countries bordering)
2301(S) (types of fisheries, also effects of oceanographic upwelling on the fisheries)

Atlantic Ocean, north, northeastern, and northwestern
1977 (management of multiple resources in northern)
2031 (role of NEAFC & ICES in management of NE fisheries)
2401–2452 (regional & other case studies of northern fisheries (Technical Session IV Section 5 & report))
2402 (management & development of northern fisheries)
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2436 (fishery regulations in the ICNAF area)
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2282(F)(regional development of W Africa fisheries)

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2301(S) (economics & development of W African coast fisheries)

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  2373 (development & present status of bottomfish resources)

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  1986 (gap between theory & practice re use of unit in Antarctic baleen whaling)
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Bogdanov, A. S.
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  2070 (salmon vessel license control plan)
  2348 (re international aspects of N Pac. fisheries)

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  2070 (Canada's experience in license limitation regulations)

Campleman, G.
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Canada (*see also* Great Lakes)
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  2077 (South Africa limitation of number of)
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  2276 (7 examples of fisheries development problems in countries bordering the E Central Atl. Ocean)
  2312–2344 (regional & other, Indian Ocean (Technical Session IV-3 & report)
  2348–2399 (regional & other N Pac. Ocean (Technical Session IV-4 & report)
  2368 (promoting Korean fisheries development through fishermen's training)
  2402–2452 (regional & other, N Atl. Ocean (Technical Session IV-5 & report)
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  2109 (present & possible, of fisheries by various countries, areas, & species) re traditionally exploited species)
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  2485 (of the Future (Closing Session of Conference))

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    Inter-American Tropical Tuna Commission (IATTC)
    International Commission for the Conservation of Atlantic Tuna (ICCAT)

International Council for the Exploration of the Sea (ICES)
International Commission for the Northwest Atlantic Fisheries (ICNAF)
Intergovernmental Oceanographic Commission (IOC)
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2236 (case study of establishment of a food fish industry for a developing country)
2328 (fishery joint ventures in developing countries)
2512 (Conference recommendations re enlistment of industrial skills of developed countries' fisheries by developing countries' fisheries)

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2335 (Indonesian fisheries)
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2368 (promoting through fishermen's training in Korea)
2373 (& present status of Bering Sea bottomfish resources)
2402 (N Atl. fisheries)
2427 (of national fishery quotas by ICNAF)
2456 (re distant-water fisheries)
2490 (impact of technical; on world fisheries problems, opportunities, & management)
See also:
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2490 (technical development impact on problems & opportunities in world fisheries & their management)

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2463 (Ghana's experience in expanding from artisanal to distant-water fisheries)

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2386 (re Pac. salmon fishery management in USA)
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2486 (quota or control measures in Peruvian, South African, & Canadian industry)

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Insull, A. D.
2490 (technical development impact on problems & opportunities in world fisheries & their management)

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2471 (re scientific management of high-seas tuna & related species fisheries)

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2444 (re management of sea herring fisheries)

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2393 (re Pac. halibut fishery management; also history of)

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1959; 2402 (responsibilities)

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1959 (scientific advice to fisheries bodies through international working parties)

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2059 (financing resources for fishery development)

Lyubimova, T. G.
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MacKenzie, W. C.
2065 (reconciling conflicts among different economic groups in fisheries management)

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[1] This section of the index to this issue prepared by Dr W. E. Ricker, Chief Scientist (retired) of the Fisheries Research Board of Canada.

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Conférence technique sur la gestion et le développement des pêches
Conferencia técnica sobre administración y desarrollo pesqueros

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